THE UNIVERSITY OF ALBERTA

THE EFFECT OF STRENGTH TRAINING UPON SPEED OF MOVEMENT AND REACTION TIME IN A KNEE EXTENSION MOVEMENT

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ABSTRACT

The purpose of the study was to determine the relationship between changes in strength of the quadriceps muscle and changes in reaction time (RT) and in movement time (MT) in a knee extension movement. Sub-problems investigated were the relationship between initial reaction time and speed of movement plus the relationships between initial strength and speed of reaction and between initial strength and movement time.

Forty-five males at the University of Alberta, the majority enrolled in the required Physical Education program, participated in the study. After initially being measured on reaction time, speed of movement and strength, the subjects were divided into groups of equal mean RT and MT. One group became the isometric training group, another the isotonic training group and the third was the control group. The exercises were performed once daily, four days a week, for five weeks.

The isometric exercise program consisted of three, six-second maximal contractions, one at each angle of 115 degrees, 135 degrees and 155 degrees. The isotonic group lifted a maximal weight from the 90 degrees flexion position to the 165 degrees extension position over a six-second period, three times.

After 2½ weeks of strength training all subjects were re-tested on RT, MT and strength and again at the end of the training session. The particular movement was to swing the lower leg as quickly as possible through a 68 degree arc.

It was concluded that 5 weeks of strength training caused significant strength increases in both training groups, but there was no statistically significant group difference in strength. There were no

statistically significant differences in speed of reaction or speed of movement on either the half-way test or the final test. There were no statistically significant correlations between changes in strength and changes in either speed of reaction or speed of movement.

On the initial test, a statistically significant relationship was found between reaction time and speed of movement (r = 0.538). This significant relationship was verified on a second initial test (r = 0.629). Both were statistically significant at the .01 level. Strength and speed of movement were also found to be significantly correlated at the .01 level (r = -0.504). Reaction time and strength correlated significantly at the .05 level of confidence (r = -0.357).

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Very few studies have been found in the literature pertaining to the effect of an increase in strength upon reaction time (RT) and speed of movement (MT). Clarke and Henry (1) studied the effect of a ten-week training program upon RT and MT in a lateral adductive arm movement. They compared the strength/mass ratio of the preferred arm to reaction time and movement time, concluding that increased strength brought no appreciable change in RT but that individual changes in the strength/mass ratio did correlate with individual changes in the speed of a lateral adductive arm movement ($r = 0.405$). Pierson and Rasch (2) conducted a test and re-test of speed of arm extension before and after a four-week weight training program, concluding that increases in general arm strength did not affect RT and MT. Henry and Whitley (3) found no significant correlation between speed of movement and strength in a lateral adductive arm movement. These results were confirmed by Clarke(4), Henry (5) and later by Smith (6).

Until the late 1940's and early 1950's, athletes had done very little weight training or specific muscle development for fear of "muscle boundness". Zorbas and Karpovich (7) studied the effect of a weight training program on the ability to turn a bicycle crank as fast as possible, concluding that the weight-lifters were faster in rotary motions of the arm than the non-lifters. In a similar study, Wilkin (8) concluded that the"chronic" weight-lifter was not muscle bound in the sense that speed of movement was impaired and that one semester of weight training had no slowing effect on the speed of an arm movement. However Meisel (9) designed a program aimed specifically at

developing the strength of the legs and concluded that the program of progressive weight resistance exercises caused a loss of speed in running ten yards.

There has also been much controversy over the relationship between reaction time and movement time. Pierson (10) and Youngen (11) both found low but statistically significant correlations between RT and MT in a forward arm thrust over a distance of eleven inches. Youngen used female subjects and Pierson used subjects ranging in age from eight to eighty-three years, whereas most of the other experimenters in this area have used male college students. In a previous study on the forward arm thrust of fencers and non-fencers, Pierson (12) found no statistically significant correlation between RT and MT. Also using an eleven-inch forward arm thrust, Mendryk (13) found no statistically significant correlation between RT and MT in any of the three age groups: 10 to 13, 19 to 25 and 40 to 55 years.

The Problem

The main purpose of the study is to determine the relationship between changes in strength of the quadriceps muscles and changes in reaction time (RT) and movement time (MT) in a knee extension movement. Programs of isometric and isotonic exercises were designed for specific development of quadriceps muscle strength.

The following problems will also be examined:

(1) the relationship between RT and MT.

(2) the relationship between strength and RT and between strength and MT as used in this study.

Limitations

In studying the relationship between strength increases and changes in MT and RT, it was necessary to limit the study to the

following:

1. Only male college students enrolled at the University of Alberta, at Edmonton, were included in the test.
2. The test was limited to a duration of five weeks.
3. Only the quadriceps femoris of the favored, or dominant, leg was tested.
4. The movement time tested was that time required for a leg extension through an arc of 68 degrees.
5. Only two types of strength training programs were used, specific programs of isometric and isotonic training.

Hypotheses

The null hypothesis is assumed throughout the thesis.

(1) Changes in strength have no effect upon changes in reaction time or changes in speed of movement.

(2) There is no relationship between strength and reaction time nor between strength and speed of movement.

(3) There is no relationship between reaction time and movement time.

Definition of Terms

1. Warning Light. In order to ensure that the subject is ready for the proper reaction, the left light will flash.
2. Stimulus Light. After an interval of one to four seconds from the flash of the warning light, another light will flash, to which the subject responds. The interval is to prevent the subject from reacting to the warning light.
3. Reaction Time (RT). Reaction time is the time that elapses

between the appearance of a stimulus and the beginning of a motor response.

4. Speed of Movement (MT). The movement time is the time that elapses from the beginning contraction to the completion of the movement, not including the reaction time. It is the time lapse from the subject's initial movement to each timing station.

5. Timing Station. Throughout the movement, the subject's leg contacts four photo-electric light beams, breaking a contact and stopping the attached chronoscope. Each one of the chronoscopes and photo-electric cells is a timing station.

REFERENCES

1. Clarke, David H., Henry, Franklin M.,"Neuromotor Specificity and Increased Speed From Strength Development", Research Quarterly, vol. 32 (Oct. 1961), pp. 315 - 325.

2. Pierson, William R., Rasch, Philip J., "Strength and Speed", Perceptual and Motor Skills, vol. 14 (1962), p. 144.

3. Henry, F.M., Whitley, J.D., "Relationships Between Individual Differences in Strength, Speed and Mass in an Arm Movement", Research Quarterly, vol. 31 (Mar. 1960), pp. 24 - 33.

4. Clarke, David H., "Correlation Between the Strength/Mass Ratio and the Speed of An Arm Movement", Research Quarterly, vol. 31 (Dec. 1960), pp. 570 - 574.

5. Henry, Franklin M., "Factorial Structure of Speed and Static Strength in a Lateral Arm Movement", Research Quarterly, vol. 31 (Oct. 1960), pp. 440 - 447.

6. Smith, Leon E., "Individual Differences in Strength, Reaction Latency, Mass and Length of Limbs, and their Relation to Maximal Speed of Movement", Research Quarterly, vol. 32 (May 1961), pp. 208 - 220.

7. Zorbas, William S., Karpovich, Peter V., "The Effect of Weight Lifting Upon the Speed of Muscular Contractions", Research Quarterly, vol. 22 (May 1951), pp. 145 - 148.

8. Wilkin, Bruce M., "The Effect of Weight Training on Speed of Movement", Research Quarterly, vol. 23 (Oct. 1952), pp. 361 - 369.

9. Meisel, Stephen Gaylor, "The Effect of a Weight Training Program On the Speed of Running", microcards, Master of Science Thesis, Pennsylvania State University, 1957.

10. Pierson, William R., "The Relationship of Movement Time and Reaction Time From Childhood to Senility", Research Quarterly, vol. 30 (May 1959), pp. 227 - 231.

11. Youngen, Lois J., "A Comparison of Reaction Time and Movement Time Measures of Women Athletes and Non-Athletes", Research Quarterly, vol. 30 (Oct. 1959), pp. 349 - 355.

12. Pierson, William R., "A Comparison of Fencers and Non-fencers by Psychomotor, Space Perception, and Anthropometric Measures", Research Quarterly, vol. 27 (Mar. 1956), pp. 90 - 96.

13. Mendryk, Stephen, "Reaction Time, Movement Time, and Task Specificity at Ages 12, 22 and 48 Years", Research Quarterly, vol. 31 (May 1960), pp. 156 - 162.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Prior to the 1948 Olympic Games, weight lifting and weight training were used mainly by body builders interested in muscle hypertrophy and strength. Very few athletes, who participated in events which required fast body or limb movements, trained with weights due to the fear of becoming "muscle bound". The popular conception was that large, strong muscles would slow down a person's speed of movement as well as restricting his range of movement. However, when a few of the Olympic Games' winners revealed that they had trained with weights, many of those who had not previously trained by such methods began to do so. Weight training then became a popular method of training, especially during the "off" season. With the increase in the popularity of training with weights came a number of investigations pertaining to the effect of strength development upon speed of movement. Some of the studies involved specific muscle strength development, while others were concerned with general strength development through a weight training program. Meisel (1) concluded that strength development decreased the subject's speed of movement; Pierson and Rasch (2) demonstrated that strength development had no effect, while others found that strength did improve speed of movement. The review will deal with studies in this respective order. Also included will be a review of the studies correlating strength and speed of movement.

1. Studies Revealing a Loss in Speed of Movement Due to Strength Training. Meisel (1) found a loss of speed in running ten yards, after a six-week weight training program. One hundred and four male university students were divided into an experimental and a control group

and were equated on the basis of time required to run ten yards after a 15-yard "free" start. The experimental group participated in a six-week weight training program composed of exercises designed specifically for strength development of the legs while the control group participated in no organized exercise. The exercises included heel raises, squats, leg flexion and gluteal pull. Strength was measured by a back and leg dynamometer. Results showed a significant increase in the leg strength of the group using the progressive resistance weight training program. The experimental group also showed a loss of speed in the 10-yard sprint, a decrease significant at the three per cent level of confidence. The control group showed no significant differences in either strength or speed of running.

2. Studies Revealing No Change in Speed of Movement From Strength Training. Pierson and Rasch (2) demonstrated that increases in general arm strength did notaffect the speed of reaction or arm extension. They state (2:144):

> One of the assumptions implicit in the use of weight training in athletics is that increases in strength are accompanied by increases in speed of movement. Although it has been demonstrated that stronger subjects are not faster than weaker, little has been done to determine the effects of limb-strength development on limb speed. The purpose of the present study was to investigate the effect of the development of arm strength on RT and MT.

Twenty-six subjects participated in a four-week weight training program, exercising three times per week. Measurements were made of their RT and MT in an 11-inch forward arm extension movement, both before and after the exercise period. Each exercise bout consisted of three sets of five repetitions of two-hand military presses, two-hand curls, two-hand reverse curls and the two-hand supine press. Strength increases were found to be significant in all four exercises,

but the RT and MT measures were no related to the total strength increases (r's of -0.23 and -0.28 respectively).

3. <u>Studies Revealing Improvements in Speed of Movement From Strength Training</u>. Chui (3) conducted one of the first studies pertaining to weight training and athletic power. Although most of the items in the study were concerned with power events, such as putting the shot, one item was concerned with speed of movement. One group participated in an intensive weight training program twice a week for three months, while the other group acted as the control group. A retest at the end of the program showed that 17 of the 22 subjects had a mean improvement of 0.33 seconds in a 60-yard spring, gains varying from 0.1 to 0.6 seconds. Four subjects showed no difference in time and one subject was 0.1 seconds slower. From this Chui concluded (3:193): "These results indicate the probability of increasing speed through training with systematic weight training exercises." However, the significance of the differences between the groups was not calculated.

Zorbas and Karpovich (4) investigated the effect of weight lifting on the speed of muscular contractions. A non-weight lifting group of 300 subjects was compared to an equal number of weight lifters in the speed of turning a bicycle crank for 24 complete revolutions. Results showed the weight lifters to be faster in rotary motions of the arm than the non-weight lifters. The muscles of the arms and upper girdle were investigated as the authors felt that these muscle groups received the most attention in weight lifting. A bicycle crank was mounted on the wall in such a manner that would allow the crank to be turned on a frontal plane. The subject grasped the crank with one

hand and turned it as quickly as possible for 24 revolutions, the time required being recorded. Each subject took two trials, with a three minute rest between trials, the faster time being taken for the speed of movement. There was a statistically significant decrease of 0.174 seconds among the weight lifters, in movement time. The authors concluded that speed of movement could be improved through training with weights.

Wilkin (5) used three groups in a study investigating weight training and its effect upon speed of movement, demonstrating that weight training had no slowing effect on the speed of arm movement in turning a bicycle crank at maximal apeed with two hands, simultaneously. An electrical counter was read at 15-second intervals which permitted an analysis of the subject's rate of turning the crank. The control group took classes in elementary swimming and golf; one experimental group with no previous weight lifting experience trained for two months, as did a group of experienced weight lifters. Each subject was tested before the study period and retested at the end of two months. Wilkin found that weight training had no slowing effect upon speed of arm movement as measured by the rotary movement but speed of movement was not increased any more by weight lifting than by a semester of beginning golf or swimming. The experienced weight lifting team showed that the (5:369) " . . . chronic weight lifter is not 'muscle-bound' in the sense that speed of movement is impaired."

Through the use of testing apparatus similar to that of Zorbas and Karpovich (4), Masley, et al (6), found that there was no apparent deleterious effect from training with weights. An experimental group (X) participated in a six-week period of weight training and was compared to two control groups, one of which played volleyball

and one which attended a sports lecture course. Maximal speed of turning a nine-inch crank with one hand for 24 revolutions was timed, previous to the training period and afterwards, and the difference was compared to strength changes. Strength of the arm was measured by McCloy's revision of the Rogers' Strength Index. All groups increased in strength but the inactive group increase was not statistically significant. Only the experimental group showed a statistically significant improvement in the speed of turning the bicycle crank. The control group showed no statistically significant change, while the volleyball group (CV) was slower at the end of the experimental period, although not significantly so, which led the authors to state (6:313):

> This tended to indicate that strength gained through weight training may have resulted in more rapid speed of movement. However, the evidence to test the hypothesis that an increase in strength was associated with an increase in speed was inconclusive since a significant increase in strength by group X was associated with a significant increase in speed but a similar increase in strength in the volleyball group (CV) was not accompanied by a similar increase in speed.

In an attempt to obtain basic knowledge regarding some of the physiological effects of progressive resistance esercise (PRE), DeLorme, et al (7), measured the contraction time of the biceps and quadriceps muscles of ten boys. The object of the study was to determine whether progressive resistance exercise produced a lengthening of contraction time, which would be (7:86): " . . . of significance to athletes, typists, dancers and others whose efficient performance is dependent upon rapid movement." An experimental group of five boys, who participated in the PRE program four times weekly, was compared to a control group of five boys in the speed of elbow flexion and knee extension. Both groups were tested before and after

the exercise period.

When testing elbow flexion the subject sat in a special chair with the right upper arm strapped to the back of the chair, as was the opposite choulder. The forearm rested on the arm of the chair with the elbow in partial extension and the ulnar aspect of the closed fist pressed on a microswitch, which activated the electric timer. As reaction time was not in question, the subject initiated the movement at will. Release of the microswitch started the electric timer. The arm was flexed with as much speed as possible to hit a rod, breaking the circuit and stopping the chronoscope. Knee extension was tested by a similar apparatus. The patient sat on a table with the thigh strapped to the table to prevent an upward motion of the thigh and with the hands extended to the rear for support. Again the movement was initiated at will. The heel was pressed firmly against a microswitch which activated the electric timer. The knee was extended as quickly as possible, the foot striking a rod which broke the circuit and stopped the electric timer. The subjects engaged in a two-week preliminary training period, during which each subject's contraction time became more constant. Strength was measured in terms of the subject's 1 R.M., which, as the authors state (7:89) " . . . is a crude test of muscle strength; but in normal subjects, in whom it is desired only to determine gross strength, it is adequate." Biceps muscle strength showed a mean increase of 59 per cent (a range of 50 to 71 per cent) while the mean quadriceps strength increase was 49 per cent (a range of 28 to 70 per cent). The speed of elbow flexion after the exercise period was found to be the same as that at the beginning in both groups. However, both groups showed a significant decrease in mean contraction time for knee extension,

from the pre-exercise to the post-exercise test. The authors explain the reduction in movement time, stating that (7:91):

> All members of both the control and the exercise group showed a reduction in contraction time and in all probability this was due to some undetected alteration in technique or apparatus. Since, however, all subjects of both groups were subjected to this factor the validity of the data is not destroyed.

Thus, the authors conclude (7:92): "The results of the post-exercise contraction time tests offer no evidence that the progressive resistance exercise produced a slowing of contraction time in those subjects."

Endres (8) felt that while there was general agreement that weight training activities did not result in a slowing of muscular movement, there was also no experimental evidence to indicate that weight training, when applied to particular muscle groups, had any positive influence on the speed of movement of these muscle groups. Three groups of subjects were equated on the basis of speed of an elbow flexion and extension with a four-pound weight. Group A trained with a four-pound weight while Group B trained with an eight-pound weight, both for four weeks. Group C, the control group, did not exercise with weights, except during the test period. The speed with which the subject could flex and extend his elbow once, while holding a four-pound weight, was measured before the exercise period began, at the end of the second week and at the end of the study. The two experimental groups took part in 16 exercise sessions in 26 days. For each exercise period the subject sat in an erect position, upper arm at right angles to the lower arm which was resting on the thigh and with the weight in the palm of the hand. The movement involved full flexion of the elbow followed by extension until the forearm made contact with the thigh and the knee. One bout consisted of

flexion and extension at maximum speed for ten seconds. One exercise period consisted of four bouts with a minute rest between bouts. One experimental group trained with eight-pound weights while the other experimental group used four-pound weights. Strength measurements were taken on a Martin dynamometer. The subject being tested assumed a supine position, knees at a comfortable angle, and the forearm at a 45 degree angle to the upper arm. Three trials of elbow flexion were taken, with ten-second rest periods between trials, the highest reading being used. Elbow extension strength was measured in a similar manner, except that the forearm was at a 30 degree angle to the table top. Both experimental groups were found to increase in daily performance scores in speed of movement, reaching a temporary plateau after the fifth session and then another one over the last four sessions. Speed of movement was found to have increased over 80 per cent for both groups, with no statistically significant difference between the two different weight groups. The authors concluded that (8:31):

> As a result of this experiment there is evidence that weight training exercises do not have a detrimental effect upon the speed of elbow flexion and extension. On the contrary, overload exercise enhanced the speed of such movement, not only when the muscles were working against the load at which they had been trained, but also when the load was reduced to a fraction of this weight. Paralleling the increases in speed of movement, there occurred marked increases in strength.

Kurt (9) demonstrated that weight training was effective in improving response time. Of 23 subjects in the study, only five showed slower response times after participating in a general "all body" weight training program twice a week for a twelve-week period. The response time test consisted of reacting to a stimulus light and moving approximately two feet to press a button, stopping the chronoscope. The subject stood in a circle, two feet in diameter, and approximately ten

feet away from four stimulus lights. Four response keys were placed on posts 54 inches in height and approximately two feet beyond the subject's normal reach. Each was placed at a 45 degree angle to the subject's sagittal plane. A verbal warning was given, a stimulus light flashed, starting a chronoscope, and the subject quickly moved to the corresponding response key to stop the chronoscope. Each subject was tested before and after the exercise period, each test consisting of 40 trials. Kurt states (9:24): "The results of this study would lead the writer to believe that a popular conception that weight training produces slowness and inaccuracy of movement . . . is not based upon sound evidence."

Meadows (10) found a significant improvement in the speed of an offensive football charge by two experimental groups of experienced football players, one performing isometric exercises and the other a general weight training program. The increase in the speed of the charge was found to be statistically significant at the .01 level of confidence for both groups, with no statistically significant difference in improvement between the two groups. All subjects were tested on speed and force of the football charge as well as back and leg lift strength tests previous to the study and were randomly assigned to one of three groups for a ten-week training period. The isotonic group engaged in a general "all body" weight training program three times a week while the isometric group engaged in a program in varied body positions for the same length of time and frequency as the isotonic group. The control group engaged in only its regular physical education period. Isometric exercises consisted of eight exercises for two bouts of six seconds at two-thirds maximal strength against a cable, pull being measured by a cable tensiometer. The body parts exercised

were hip extension and flexion, knee extension and flexion, shoulder extension and flexion and elbow extension and flexion. The speed of charge was measured from a footgall three-point stance, rear foot pushing against a standard starting block, right hand pressing on a microswitch. Six feet directly ahead of the subject was a twine finish line, which, when it was hit, depressed a microswitch to stop the chronoscope. The charge was initiated at will. Release of the microswitch started the chronoscope which stopped when the finish line twine was hit. Both experimental groups showed a statistically significant difference in strength from the control group, but there was no statistically significant difference between the two methods of exercise. Speed of the offensive football charge decreased significantly at the .01 level of confidence, the isotonic group showing a mean performance improvement of 0.031 seconds and the isometric group showing an improvement of 0.022 seconds. These findings led the author to conclude that (10:92) " . . . both the isotonic and isometric muscle contraction training improved significantly the speed of the offensive football charge in comparison with the control group that did not undergo a muscle contraction training program."

In a study of movement time and reaction time and the effect of strengthening the muscles on both, Clarke and Henry (11) found a significant correlation ($r = 0.405$) between individual changes in the strength/mass ratio and individual changes in the speed of a horizontal adductive arm movement, through a distance of 117 cm. The effective mass of the right arm was determined by weighing and was combined with the static dynamometric strength to form the strength/mass ratio. Two groups, each of 31 male college students, refrained from participating in organized athletics or physical education classes, the

control group doing no exercising and the experimental group participating in a ten-week weight training program. None of the exercises performed by the experimental group involved the test movement. The test movement consisted of a horizontal adductive arm movement over an arc of approximately 110 degrees. The subject stood with shoulders and back against a wall and the right arm extended laterally, the hand resting on a reaction key. In response to the auditory stimulus, the subject adducted the rigid arm as quickly as possible to touch a vertical string, which stopped the second chronoscope. The auditory stimulus started the R^T chronoscope, which stopped upon release of the reaction key and the MT chronoscope started. No appreciable change in arm mass or reaction time occurred in either group. The control group declined 8.7 per cent in both strength and S/M ratio. The mean strength gain by the experimental group was 17.9 per cent. However, no significant correlation was found between individual differences in speed and S/M ratio, for both tests (r = -0.255 and r = 0.322 respectively). Thus the authors concluded (11:235):

> 1. Conditioning exercises of the progressive resistance type that do not directly involve a lateral arm test movement apparently cause increased mean arm strength in the test position and increased mean speed of the test movement.
>
> 2. In the arm movement studied, individual differences in the amount of change in the strength/mass ratio have a low but significant correlation with individual changes in maximal speed of movement.

4. Studies Pertaining to Strength and Speed of Movement. Rasch (12) found no significant correlation between measurements of weight, length and strength of the hand, forearm and arm and the speed of movement of each of these body segments. Utilizing the apparatus as previously described (2), he studied the speed of movement of the hand over a distance of six inches, the forearm over a distance of 14 inches, and the

arm over a distance of 20 inches. The strength of each segment was determined by measuring the pull exerted against a Chatillon Improved Spring Balance, Type 34 H. The correlation coefficients, as computed by the Pearson product-moment method, revealed no statistically significant correlation. Thus, the author concluded (12:332): "It may be concluded from the experimental results of this study that no definite relationship can be found between speed of arm movements and the size or weight of the arm."

In an effort to determine the relationships of reaction time, movement time and completion time to strength and other anthropometrical measurements, Glines (13) tested both total body movement and arm movement, reaction time also being taken. Strength of a number of muscle groups was measured by the cable tensiometer method and the Rogers'Strength Index (P.F.I.) battery. In the total body movement test, the subject stood on two switch mats, containing microswitches to control the chronoscopes. After a verbal warning signal, the stimulus light flashed and both chronoscopes started. When the subject released the pressure on either switch mat, the RT chronoscope stopped. The subject ran as fast as possible to press another switch mat ten feet away. This stopped the completion time chronoscope. Movement time was determined by subtracting the reaction time from the completion time. Arm movement time was the length of time required to move the left hand from the switch mat to the target mat 18 inches away, both on the same table. After a verbal warning signal and at the flash of the stimulus light, the subject moved his hand from one mat to the other. Release of pressure on the switch mat stopped the RT chronoscope and pressure on the target mat stopped the completion time chronoscope. Movement time was determined in the same manner as

described for total body MT. No statistically significant correlation was found between strength and either body RT or arm RT. A significant correlation (r = 0.58) was found between the Physical Fitness Index and the total body MT. A significant correlation (r = 0.37) was found between strength and arm movement time.

Henry and Whitley (14) found no significant correlation between static strength and "strength in action" (14:24) in two horizontal adductive arm movement tests involving 65 male college students. The effective arm mass was measured with the subject in a supine position on a table, the preferred arm extended laterally on a plywood board. One end of the board was hinged to the table and the other end was suspended from a spring scale. Strength measurements were taken with the subject in the same supine position. A board, which was connected to a dynamometer hooked to the floor, was strapped on top of the subject's arm. The subject then lifted his arm upwards at maximal strength, measurements being recorded on the dynamometer. Two tests of speed of movement were administered, both from a standing position, with the back against the wall and right arm extended laterally, hand resting on a microswitch. A verbal warning signal was given and on the stimulus light the subject swung his arm as quickly as possible forward and to the left past the medial plane of the body to strike a target with maximal force. In the first experiment the target was a free-hanging towel suspended 17 cm. past a vertical string, which was positioned at arm's length directly opposite the subject's right shoulder. The RT chronoscope started upon illumination of the stimulus light and stopped when the microswitch was released, the MT chronoscope starting at the instant of release. The subject hit the vertical string, which pulled out a contact, thus breaking the circuit and stopping the

MT chronoscope. The shoulder rotation was approximately 90 degrees, and the distance moved was a constant 100.1 cm. In the second experiment the vertical string was positioned in the medial plane, the average distance of movement being approximately 125.3 cm., through an arc of a constant 109 degrees.

The strength and mass measurements were combined to form the strength/mass (S/M) ratio, which was correlated with the speed of movement. From both experiments the correlation between speed and S/M ratio was found to be very low, neither being significantly different from zero (r = -0.039 and r = -0.160 in experiments 1 and 2 respectively). The authors state (14:32 - 33):

> The results of the two experiments support the conclusion that individual differences in static strength cannot predict "strength in action", in particular as it is exhibited by maximal speed of movement in a 90 degree horizontal arm swing from the shoulder pivot . . . . The data strongly suggest that the acceleration curve for the arm movement is predominantly ballistic rather than linear.

In a follow-up study, Henry (15) repeated the horizontal adductive arm movement (14) but used a series of 7 timing stations, spaced approximately 17 degrees apart, to determine any ballistic effect. Since reaction time was not tested, the movement was initiated at will. Release of the starting microswitch started all 7 chronoscopes, each stopping as the subject hit the corresponding vertical timing string. The arm described a horizontal arc of approximately 120 degrees. Strength and effective arm mass were measured as previously described (14). Correlations were computed between mean individual strength/mass ratios and individual mean speeds at each successive timing station, and were found to be very low. Correlations between the S/M ratios and net speeds of movement were found to be of a low statistical significance. Henry concluded (15:447):

. . . .

3. Measured static strength available for a movement and speed in that movement are possibly correlated to a slight degree; the relationship is difficult to establish and too small to be of practical importance.
4. The low relationship between static strength and speed of movement supports the hypothesis of high neuromotor specificity.

Clarke (16) continued the investigation of the relationship between individual differences in arm speed, strength and mass, finding a non-significant correlation between the S/M ratio and speed of movement ($r = -0.277$), which verified the results of previous studies (14, 15). The test for arm speed was similar to that used by Henry and Whitley (14), except the distance the arm moved was 117 cm. before stopping the second chronoscope. Effective arm mass was measured with the subject supine on a table, his preferred arm on a plywood board which was hinged to the table at one end and suspended from a spring scale at the other end. The arm was placed so that the shoulder joint was over the hinge. Strength was also measured with the subject supine on a table, with his arm extended laterally, strapped to and under a plywood board, which was attached to a hook on the floor by a dynamometer. The subject pushed up on the board and the force exerted was recorded on the dynamometer. A correlation between strength and speed of movement was found to be not of statistical significance ($r = -0.369$). The author's conclusion was that speed of an arm movement cannot be successfully predicted from a knowledge of muscular strength.

Smith (17), in studying individual differences in limb strength and speed, found that the speed of a limb movement was completely unrelated to both the S/M ratio and static strength. The measurement of the effective arm mass was determined as previously described (14, 15,16). Leg mass was measured in a similar manner, with the leg on a plywood board, hinged to the table at one end and the other end

suspended from a spring scale. Strength measurements were determined with the subject in a standing position with his back pressed against a wall, his leg against a vertical post and grasping the framework with his free hand. Directly under his shoulder was a vertical, adjustable post to which a horizontal lever was attached. The subject extended his arm laterally and pushed forward against the lever. The force exerted was measured by a dynamometer. Then the subject pushed backward, so that both forward and backward strengths were recorded. To determine leg strength the subject stabilized himself by holding on to a heavy table and moving his leg forward against a dynamometer. Again both forward and backward strengths were determined.

Arm speed was measured in the same manner as described by Henry and Whitley (14). Both adduction and abduction speeds were measured over a distance of 80 cm. The speed of leg movement was determined with the subject standing upright and kicking forward, with a straight leg at maximal speed to hit a target 70 cm. in front. The heel rested against a microswitch, which started on the flash of the stimulus light and stopped upon release of pressure on the switch, with the second chronoscope starting. When the target was hit, a string behind itpulled out a metal chip which broke the circuit and stopped the second chronoscope. Reaction time was determined from the first chronoscope, speed of movement from the second. Backward speed was measured with the toe touching the microswitch and the heel hitting thetarget. In all cases of correlation, the coefficients were found to be nonsignificant, indicating that static strength and MT plus static strength and the S/M ratio are independent of each other.

Henry, <u>et al</u> (18), measured reaction time and maximal limb speed in six movements in one experiment using a group of 80 college men.

Another group of 70 was used for the determination of reaction time, speed of movement, strength and the S/M ratio in four different movements. In experiment I the subjects made an overhand throwing movement a distance of 28 inches with both the left and the right hand. Then they performed a forward leg kick of 28 inches with both the right and left legs. A frictionless two-hand arm crank was placed at the subject's standing shoulder height and the subject turned the crank as many times as possible in 30 seconds. This test was repeated using both legs. For the throwing motion the subject stood with his upper arm extended laterally from the shoulder and the lower arm extended upwards, index knuckle placed on a microswitch. On the flash of the stimulus light the arm was swung forward and down in an arc to strike a suspended tennis ball. Again the RT chronoscope started with the stimulus light and stopped with the release of the microswitch, the MT chronoscope starting at this same instant of release, and stopping when the tennis ball was struck. The forward leg kick measurements were determined with the subject performing a football kicking movement. The RT and MT measurements were determined in a manner similar to those of the arm movement.

In experiment II the subjects made an adductive horizontal swing of 31.5 inches and 70 degrees both forward and backward, as described by Henry and Whitley (14) and Smith (17). The speed of forward and backward stiff-legged kicks, over a distance of 27.5 inches, as described by Smith (17), was also measured. The effective arm and leg mass was also measured, as described by Henry and Whitley (14), to determine the S/M ratio. Their results revealed no statistically significant correlations between strength and speed of movement and the ratio of strength/mass with limb speed.

Clarke and Glines (19) measured 13-year old boys to determine the relationships of reaction, movement and completion times with various strength and anthropometric measures. Total body and arm movement times were determined as explained by Glines (13). Three trials of each were made, the fastest time being recorded. Reaction time was found to have no statistically significant correlation with arm strength ($r = 0.09$). Total body movement was found to correlate significantly with arm strength ($r = -0.39$) and the Strength Index ($r = -0.36$). There was a statistically significant correlation between arm strength and the speed of the arm movement.

Studies Related to Quadriceps Strength Development

1. Isotonic Exercise. Prior to the mid-1940's, rehabilitation for many types of joint injuries and diseases was administered by the use of training exercises of the low resistance, high repetition type (20). In this type of exercise, the patient lifted a relatively light weight a great number of times. Through this method rehabilitationists hoped to restore the patient's strength to normal. Invariably, they were not always successful. Another method of rehabilitation was through riding a stationary bicycle or walking, both being weight-bearing exercises.

In 1945, DeLorme (20) developed a new method of rehabilitation, using a completely different technique. He felt that the technique of low resistance, high repetition exercises developed endurance instead of power, the only value being to increase joint motion. He felt, however, that his technique brought forth all of the potential strength of the muscle. Also, since the rate and extent of muscle hypertrophy was realized as being proportional to the resistance that the muscle must overcome, it was felt that strength would return faster by using the high resistance, low repetition type of exercise rather than through

the use of low resistance, high repetition exercises. His theory was to use the new method to develop power in the atrophied muscles of the injured joint until it was of equal strength to that of the opposite side and then to develop endurance in both sides. For instance, after a menisectomy, or for an unstable knee, the thigh muscles of the injured side would be exercised until the power was equal to that of the contralateral limb. Then both thighs would be exercised for the development of endurance. The patient determined the maximum weight that could be lifted to full knee extension and then lowered once. This was called the 1 R.M. Training and was conducted once per week with this resistance. He also determined the maximum resistance that could be lifted to full knee extension, and then lowered, ten times. This was called the 10 R.M., and was performed on the remaining four days of each week.

Determination of the 10 R.M. and 1 R.M. tended to be more or less by trial and error. Both were determined on the same day, first the 10 R.M. and then the 1 R.M. Weights were added to the "training boot" and the patient extended his knee in a series of ten repetitions until he could only lift the weight through ten repetitions. Weights were then added until the patient could only lift and lower the boot once, this being his 1 R.M. These measurements were taken prior to commencement of the study and were re-determined on the sixth day of each week, over the course of the study. Due to the great amount of fatigue developed while determining the exercise resistances, the seventh day of each week was for rest. During each training session the patient actually performed from 70 to 100 repetitions, in series of ten repetitions. Hence, it was necessary that the patient started out with lighter weights and worked up to his maximum.

In each training session the patient sat on the training table with knees flexed to 90 degrees. A folded blanket or pad was placed under the knees so that the lower leg would be parallel to the floor, when fully extended. A boot was strapped on the foot. Attached to the bottom of the boot was a steel plate, which held an iron pipe for holding the resistance. Resistance was in the form of iron plates, varying in weight from 1¼ to 25 pounds each. The required weights were added and the patient performed the exercise. DeLorme stressed the importance of full extension of the knee for optimal development of the vastus medialis muscle, as it functions mainly during the last 15 degrees of extension. The leg was extended and lowered at the same rate so that the movements were done " . . . smoothly, rhythmically and without haste, but not so slowly that the mere holding of the weights will tire the patient" (21:609). Quick or sudden movements were avoided.

DeLorme (21) studied the effects of the high resistance, low repetition type of exercise on 300 subjects and found good response in muscle hypertrophy and power, as well as symptomatic relief. He also stressed the importance of this technique as a non-weight-bearing type of exercise, rarely causing swelling and fluid which frequently resulted from such weight-bearing exercises as walking or riding a stationary bicycle. From his results he concluded that (21:630):

> 1. High resistance, low repetition exercises build powerful muscles, whereas low resistance, high repetition exercises produce the quality of endurance.
>
> 2. Weakened, atrophied muscles should not be subjected to endurance-building until the power muscle has been restored to normal by power-building exercises.
>
> 3. Restoration of muscle power with return of motion in a limb has been neglected in the past. It is in most instances preferable to have a limited range of motion with good power rather than to have normal range of motion with inadequate power.

. . . .

> 6. Knees unstable either from loss of ligamentous support or muscle atrophy should refrain from full weight bearing activities until the quadriceps power has been restored by non-weight bearing exercises.

In a later study, DeLorme and Watkins (22) changes the term "heavy resistance exercises" to "progressive resistance exercises" as they felt that the former term could be interpreted incorrectly in its usage. Experience gained since DeLorme's original exercise technique had demonstrated that 70 - 100 repetitions was too high a number, causing extreme muscle fatigue, whereas 20 to 30 repetitions was considered to be optimal in that heavier loads could be used, thus bringing about faster and larger gains in strength and muscle hypertrophy. The ten repetition maximum was determined as in the original technique and the patients trained in the same manner except they only performed three sets of repetitions, instead of 7 to 10 sets. The exercise schedule was (22:264):

> First set of 10 repetitions use ½ of 10 repetition maximum
> Second set of 10 repetitions use 3/4 of 10 repetition maximum
> Third set of 10 repetitions use 10 repetition maximum

DeLorme et al (23), conducted a study on the effect of progressive resistance exercises on the quadriceps muscles of poliomyelitis patients. Nineteen patients were divided into three groups, each of a different exercise treatment. One group, consisting of patients whose quadriceps were of sufficient strength, performed the regular exercise of extending the knee against gravity from a sitting position. The second group performed their exercises from a supine-sitting position with legs straight along the table top, feet pressing a spring-loaded pedal. The tension on the spring could be varied to allow progressive exercise. Release of the pressure on this pedal pushed the foot back towards the body, flexing both the hip and the knee. Extension of the hip and knee

pushed the pedal back to its original position. The third group, with the weakest quadriceps muscles, performed their exercises from the prone-lying position. A cable attached to the patient's foot passed through a series of overhead pulleys to hold a suspended weight of pre-determined size. The weight offered sufficient resistance to raise the patient's lower leg to the vertical and to allow the patient to lift it by extending his knee.

All three groups performed 30 repetitions, once daily, four days a week. The 1 R.M. and 10 R.M. determinations were made on the fifth day. Strength was measured by the spring scale, work capacity by the ergograph.

Improvement was found in most cases, except for three where there was no improvement. Due to individual differences, strength development was not at the same rate for everyone, some being much slower than others. The authors concluded that following acute anterior poliomyelitis, any remaining innervated muscles responded to progressive resistance exercises with an increase in strength and work capacity in a manner similar to normal muscles.

Krusen (24) studied two different exercise routines in an attempt to develop a program for strengthening quadriceps muscles weakened by poliomyelitis. Both routines used one repetition maximum and five repetition maximum, training once daily for ten weeks. The subjects used in the study all had weakened quadriceps muscles. The two exercise routines were:

Routine I

1. The first set of 5 repetitions, use 25 per cent of 5 R.M.
2. The second set of 5 repetitions, use 50 per cent of 5 R.M.
3. The third set of 5 repetitions, use 75 per cent of 5 R.M.

Routine II

1. The first set of 5 repetitions, use 100 per cent of 5 R.M.
2. The second set of 5 repetitions, use 125 per cent of 5 R.M.
3. The third set of 5 repetitions, use 150 per cent of 5 R.M.

Again complete extension was stressed. This, however, was not possible when the subjects tried to perform the five repetitions with 125 and 150 per cent of their five repetition maximum. He found that all of the subjects in the study gained strength, increasing almost as a straight line function over the ten week period of the study. The percentage gain in strength was found to be greater in the weaker muscles than in the stronger, but the absolute strength of the stronger muscles increased more rapidly than that of the weaker muscles.

According to Gallagher and DeLorme (25), the basic principle of progressive resistance exercise was that muscle power was better developed when the muscle was exercised at its maximum capacity than when the muscle repeated an exercise many times against less resistance. They re-investigated the problem of knee injury rehabilitation using the 10 R.M. technique, with the modifications by DeLorme and Watkins (22). The twenty-five subjects performed thirty repetitions once daily, four times a week, using the fifth day to determine the new 10 R.M. As in the previously stated modifications (3), the subject performed three sets of ten repetitions, the first set at one-half 10 R.M., the second set at three-quarters 10 R.M. and the third set at the full 10 R.M. They found over 300 per cent increase in the weight lifted, indicating a significant strength increase.

DeLorme, <u>et al</u> (7), divided ten adolescent boys into two groups, an experimental group and a control group, to determine whether progressive resistance exercises shortened muscle contraction time and

if these exercises were of significance to athletes and dancers. Anthropometric measurements were taken of the upper arm and thigh to determine any changes in size due to hypertrophy. Strength was measured in terms of the amount of weight lifted in one maximal repetition. The experimental group received progressive resistance exercises four times per week for four months and a new 1 R.M. was determined each week. The subjects took part in a two-week preliminary trial period of 10 to 18 contractions per day in an attempt to equalize the strength of the subjects before beginning the actual study.

The results showed an increase in arm and thigh circumference measurements in the experimental group. Thigh circumference increases ranged from ½-inch to 1 3/4 inches. There was considerable increase in the one maximum repetition and muscle hypertrophy indicating strength increases.

McGovern and Luscombe (26) modified two well-known techniques in an effort to determine a clinical progressive exercise technique where therapeutic benefits would not be sacrificed but time consumption would be decreased. One group, exercise A, was a modification of the DeLorme-Watkins technique. The subject's 10 R.M. was determined, the exercise consisting of one set of five repetitions of the 10 R.M. or one-half the ten maximum repetition, and a second set of 10 repetitions at the full 10 R.M. Exercise B was a modification of the Zinovieff, or Oxford, technique which was designed to keep all of the exercise at the maximal level allowed by fatigue, following a normal fatigue curve. This exercise consisted of:

(1) 10 repetitions at 10 R.M., following a short warm-up.

(2) One minute rest.

(3) 10 repetitions at three-quarters 10 R.M.

(4) One minute rest.

(5) 10 repetitions at one-half 10 R.M.

Five subjects, all male, were assigned to each group. Each group exercised once daily, five times per week for three weeks. The authors concluded that both modified exercise techniques produced approximately the same results as the original exercise programs and that there was no significant difference noted between the two methods tested.

Clarke and Herman (27) conducted a study by which they hoped to establish a practical method for determining the maximum resistance load for ten repetitions for the quadriceps femoris muscle group. The quadriceps strength of thirty subjects was determined by the cable tensiometer technique. The leg was placed in 135 degrees extension and the pull was by a harness around the foot, instead of the pulling strap being placed around the lower leg. Although no statistically significant relationship was determined, the authors found that a resistance load of 50 per cent of the strength, as determined by cable tensiometer, was a reasonably satisfactory method for determining the ten maximal repetition resistance.

Barney (28) compared the effectiveness of two techniques of progressive resistance exercises in strength development of the left quadriceps muscle. The 94 subjects participating in the study were normal male volunteers from the required service program and were divided into two groups, a control group and an experimental group. The control group trained using the progressive exercise technique as outlined by DeLorme and Watkins (22). The experimental group followed the same exercise program as the control group but used a different work load index. The subjects of both groups determined their 10 R.M. and 1 R.M., their maximum quadriceps power being measured by the 1 R.M. The experimental group also determined the amount of resistance each could lift to full

extension five times (5 R.M.), and seven times (7 R.M.). The experimental group performed their exercises in the following manner (28:55):

1. Lift ½ of 10 R.M., a total of ten repetitions.
2. Lift 5 R.M., a total of five repetitions.
3. Lift 7 R.M., a total of seven repetitions.
4. Lift 10 R.M., a total of ten repetitions.

Approximately one-half to one minute rest was allowed between each set of exercises.

Both groups exercised three days a week, Monday, Wednesday and Friday. The maximum resistance was determined before starting the study and was re-determined each succeeding Friday. Previous to the commencement of the study, all subjects were given two weeks of general reconditioning exercises in an attempt to equalize the general conditioning of all subjects. The results of the study were (28:136):

> 1. Significant gains in strength of the quadriceps were produced by progressive resistance exercise practised three days per week over an eight-week period.
> 2. There was little difference in the results of isotonic strength measurements between the two methods of exercise.
> . . . .
> 6. There was no direct relationship between the percentage gains in circumference of the left thigh and the strength of the left quadriceps muscle.

Barney and Bangerter (29) conducted a study comparing the DeLorme-Watkins technique of progressive resistance exercise with a "traditional bulk or hypertrophy program" and a "traditional strength program" in the development of muscular strength and hypertrophy. The study involved exercise of the left quadriceps muscle for a period of eight weeks. All subjects were given general conditioning exercises prior to the initial tests in an attempt to equalize their strength. Each subject determined his 10 R.M., which he performed three times a week. The 1 R.M. was also determined and was performed once a week. Friday of each week served as the testing day, when a new 10 R.M. and a new

1 R.M. were determined. Both were also used as an index of the strength increase.

The control group of 47 subjects followed the DeLorme-Watkins technique as designed by the authors (22). The "traditional bulk or hypertrophy program" consisted of three sets of ten repetitions, using the full 10 R.M. in each set. This group consisted of 18 subjects. The 15 subjects in the group following the "traditional strength program" performed the following exercise routine:

1. In the first set of ten repetitions, use the 10 R.M.
2. For the second set of repetitions, increase the resistance by 5 to 10 pounds and complete as many repetitions as possible.
3. For the subsequent set of repetitions, continue to increase the resistance by 5 to 10 pounds for each set, doing as many repetitions as possible until the 1 R.M. is reached, after which additional resistance is added and the subject attempts one more lift.

The results of the study indicated that hypertrophy of the left quadriceps muscle, which was measured at points four and eight inches from the superior edge of the patella, was gained only by the group using the DeLorme-Watkins technique. The gain in hypertrophy ranged from zero centimetres, in one subject, to five centimetres, significant at the 1 per cent level of confidence. On the basis of the 10 R.M. and 1 R.M. strength measures, strength increases were significant at the 1 per cent level of confidence for all three groups. The authors concluded that the DeLorme-Watkins technique of progressive resistance exercises was superior to the other two programs when both hypertrophy and strength development were desired.

2. Isometric Exercise. Until the publications on isometric contactions by Hettinger and Müller (30), the main method of exercise was conducted through isotonic contractions. In seventy-one separate experiments conducted over an eighteen month period, a group of nine male subjects performed various exercises of contracting the forearm flexors and extensors to pull and hold a pre-determined amount of tension against a spring scale. A number of significant findings emerged from these experiments and from succeeding ones. Some of these findings are summarized by Steinhaus (31:148):

1. Muscle strength increases an average of 5% per week when the the training load is as little as 1/3, or even less, of maximal strength.

2. Muscle strength increases more rapidly with increasing intensity of training load up to about 2/3 of maximal strength. Beyond this, increase in training load has no further effect.

3. One practice period per day in which the tension was held for six seconds resulted in as much increase in strength as longer periods (up to full exhaustion in 45 seconds) and more frequent practices (up to 7 per day).

In a later article (32), Müller explains the advantages of using static contractions in strength training and testing for the reason (32:41): "The maximal strength possible in a certain position during a movement is much lower than the strength in the same position reached with a static contraction." According to Müller, in a later article (33), an increase in muscle strength is due to (33:216):

> The stimulus necessary for an increase of muscle strength is an increase in the tension over that previously exerted (Siebert 1928). This means that even years of heavy work for many hours per day does not change muscular strength if the maximal tension reached during work remains the same.

In a recent book, Hettinger summarizes some of the more recent conclusions (34:75):

1. It has been shown that muscle tension, i.e., the training strength, seems to be the important point in muscle training.
2. The minimum training stimulus in muscle tension is about 1/3 of the maximum strength obtainable in voluntary isometric muscle contractions, and an exertion of 40 to 50% of the current maximum strength of the muscle gives the muscle the maximum obtainable training effect.
3. It is unnecessary to keep this tension to the point of complete fatigue of the muscle to get the maximum in training effect. A period representing 10 to 20 per cent of the time it takes to reach complete fatigue of the muscle - which prevents further holding of muscle tension - is enough to reach the maximum obtainable training effect.
4. One single training stimulus per day is adequate for the maximum obtainable training effect for a certain muscle group in a certain individual, during a certain time.

For practical purposes, in order to train the muscle for increasing muscle strength, we suggest exercising the muscle group which is to be trained by making one isometric maximum muscle contraction against a resistance each day.

As a result of the relative recency of the isometric technique of exercising, there have been relatively few studies pertaining to any effects upon quadriceps strength development. Lawrence (35) conducted an experiment to determine the effect of progressively prolonged isometric exercises upon the strength of the quadriceps over a five-week period, on one subject. The length of time that the knee could be held in a fully extended position for ten repetitions was determined by trial and error before the study began. Then a program of progression was determined for the subject. For each exercising period, the subject sat on the table edge with his knee flexed to 90 degrees. A towel roll was placed under the thigh so that the lower leg would be approximately parallel to the floor when fully extended. The exercise program was conducted as follows (35:660):

First week's exercise
10 extensions of knee sustained for 10 seconds each
10 seconds rest between extensions
Series of extensions repeated 3 times daily.
Second week's exercise
10 extensions of knee sustained for 15 seconds each

10 seconds rest between extensions
Series repeated 3 times daily.
Third week's exercise
10 extensions of knee sustained for 20 seconds each
15 seconds rest between extensions
Series performed only 1 time daily.

The fourth week conventional progressive resistance exercise using the "DeLorme Table" was begun with a 10 R.M. of 2½ pounds. The second (fifth) week of conventional PRE was 5 pounds.

The results of the case study indicated that the subject was able to walk unsupported, and with only a slight limp, after two weeks of the progressively prolonged tension exercise.

Rose, et al (36), adapted the method of body positioning and weight loading as popularized by DeLorme. The person sat on an exercising table, or plinth, with his lower leg hanging over the edge of the table, knees flexed at 90 degrees. The subject's initial 1 R.M. was determined by trial and error. The 1 R.M. in this case was the weight the subject could lift from 90 degrees flexion to full extension and maintain complete extension for five seconds. The exercise was performed once daily, five days per week. Daily increments in weight of 1¼, 2½ or 5 pounds were attempted on different groups. One and a quarter pounds was found to be the optimal increment. If the person could not lift the weight, the increment was removed and the subject performed the exercise using the previous day's resistance. If, on three successive days, the subject could not lift the weight, the subject was assumed to have reached his maximal strength. The final increase in strength was found to vary from 80 to 400 per cent more than the initial value. A follow-up study by Rose (37) produced similar results, and the optimal increment was again found to be 1¼ pounds.

Lawrence and McGrail (38) reported a case study on a method of

progressive weighted isometric exercise for rehabilitation after meniscectomy, also reviewing six other cases. The isometric exercise was used to avoid motion of the knee joint while developing the quadriceps muscle. Shortly after the operation, the patient sat on one stool with his foot supported on another stool, his knee flexed to 45 degrees and weighted sockinettes on his feet. He extended the knee fully without lifting his foot from the stool. Ten repetitions were done with 15 second rest intervals. This exercise was performed once daily, five days per week. The progression then led to extending the knee fully and lifting the weights off the stool. Then the leg was held in extension for 30 seconds, progressing to 45 seconds. Again ten repetitions were performed with 15-second rest intervals. Results showed a percentage increase in muscle strength of approximately 580 per cent.

Gersten (39) conducted a study comparing isotonic and isometric exercise methods on strength development of the quadriceps muscle in patients with muscle weakness. One leg was treated isotonically, the other isometrically, and strength was tested isometrically by a cable tensiometer. The isotonic exercise program was by the DeLorme-Watkins technique (22) of 10 R.M. and the isometric program consisted of 5 maximal contractions of 5 seconds each, with 5 second rest intervals. Results showed both methods of exercise to be almost identical in developing strength, as measured by the cable tensiometer. Strength development continued throughout the seven week experimental period. The author stated (39:504): "The ease of attaining good results with isometric exercises in patients, with minimal instruction, makes it a usable technic".

Lawrence, <u>et al</u> (40), also conducted a study comparing the effectiveness of isotonic and isometric exercise programs in muscle strength

development, which was measured by the weight load increase in the 10 R.M., in a pre-test and post-test. Both groups performed their exercises on the training table and with the weighted boot. The isotonic exercise program of 10 R.M. was that of DeLorme and Watkins (22), exercising the right quadriceps. In the isometric method, the subject lifted the weight to full extension, maintaining a maximal isometric contraction for the 30 seconds. This was repeated ten times with 15 second rest intervals between extensions. According to the increase in the weight load in the 10 R.M., strength development in the quadriceps muscle was found to be less by isometric exercise than by the isotonic method. However, endurance development was found to be greater by the isometric technique than by isotonic exercise.

Schweid, et al (41), demonstrated the possibility of obtaining significant strength increases in the quadriceps muscle of normal, healthy children through the use of brief isometric exercises. Forty-eight boys were divided into four groups, two groups aged 6 and 7 and two groups aged 8 and 9. One group at each age level was the experimental group, the other group being the control group. Both experimental groups exercised five days per week, at the beginning of the school day. The amount of resistance the subject could lift and hold at full extension for five seconds was determined and served as the muscle strength. The exercise consisted of lifting a boot loaded with the established maximum weight plus ½ pound holding it at full extension for 5 seconds. If the subject was successful, the procedure was repeated with the addition of another ½ pound. If not successful, the ½-pound weight was removed and extension was again attempted. Another ½ pound was removed, if the subject was again unsuccessful in lifting the weight. No more than three

attempts were made in one day. Results indicated significant strength increases in both experimental groups. The average of the lower age group increased from 16.4 pounds to 22.5 pounds, or 41 per cent of the body weight. The older group increased from an average initial lift of 20.5 pounds to 35.6 pounds or 55 per cent of their body weight. Girth measurement of the thigh was taken but no significant changes in thigh girth were found.

Studies Showing Reaction Time - Movement Time Correlations

1. Studies Showing a Significant Correlation. In studying the relationship between simple reaction time (RT) and movement time (MT) Pierson noted that (42:227) " . . . when subjects other than male college students are used, results indicate that there may be a positive correlation between RT and MT . . . ". This led to his investigation of the relationship between the RT and MT of 400 male subjects, ages ranging from 8 to 83, in an 11-inch forward movement of the arm. The results disclosed a significant relationship between RT and MT (r = 0.56) for the total group and a non-significant correlation (r = 0.35) for the 40 college age subjects, 19 to 25 years.

Using the same 11-inch forward movement and similar apparatus to that of Pierson (42), Youngen (43) studied the RT - MT relationship of 47 women athletes and 75 women non-athletes. Low but statistically significant correlations, at the .05 level, were found for both the athletes (r = 0.27) and the non-athletes (r = 0.25).

In another study of 11-inch forward movement of the arm, Pierson and Rasch (2) found a significant correlation of r = 0.47 before the four-week exercise program and r = 0.37 after the training session.

2. Studies Showing a Non-significant Correlation. Fairclough (44), in determining the effect of motivation upon the transfer of reaction latency and speed of movement, computed correlations between the RT and MT for an 18-inch upward and lateral movement of the right foot and an 8-inch movement of the hand. All of the correlations were found to be negative and non-significant, ranging from r = -0.074 to r = -0.405 with a mean of r = -0.278.

Slater-Hammel (45) studied the relationship between RT and MT in a horizontal movement of the right arm through an arc of 120 degrees. Correlations between RT and MT ranged between r = -0.07 and r = 0.17, all values being (45:112) " . . . well within the limits of the sampling error of a true zero correlation." He concluded (45:113): "The results of this study are interpreted as simply indicating that measurement of reaction time cannot readily be used to predict speed of movement."

Henry (46) studied the RT - MT relationship in two arm movements. One required a forward and upward movement of 12 inches to grasp a tennis ball and the other required a hand movement of 5½ inches to press a treadle. Correlations were found to be non-significant (r = 0.01 and r = 0.12, respectively), as within the limits of a true zero.

Howell (47), in a study of the effect of emotional tension upon RT and MT, found a negative correlation (r = -0.382). The movement consisted of releasing a reaction key and moving the arm six inches to grasp a tennis ball, back down to touch a switch button on the base, and up to grab a second tennis ball which disconnected the circuit.

Pierson (48) compared 25 fencers with an equal number of non-

fencers in an 11-inch forward movement of the hand and arm and found no correlation between RT and MT for either group.

Cooper (49) studied the correlation between the speed of reaction and movement in a horizontal and lateral, adductive arm swing through an arc of 120 degrees. He found no evidence of a correlation between RT and the speed of a free arm movement, concluding that RT and MT could be considered independent of each other.

Fifty college males performed a test of reacting to a stimulus light and swinging the arm up 12 inches and forward 24 inches to strike a tennis ball. In the statistical analysis, Wilson (50) found a correlation of low but questionable significance ($r = 0.308$), concluding that (50:109): "Individual differences in quickness of reaction and quickness of movement are almost completely independent."

Henry and Whitley (14) used 30 male college students in a test of a horizontal, lateral-adductive arm swing to strike a target, each subject moving an average of 109 degrees. Statistical analysis of the RT - MT correlation showed an absence of a correlation ($r = 0.059$).

From studying 105 college men in two basic movements, one a modified baseball throw and the other a football kick, Lotter (51) found that the individual differences in ability to move an arm or a leg quickly were not correlated with the speed of reaction for these movements. The arm movement consisted of hitting a tennis ball using a throwing arm movement of 28 inches. The leg movement consisted of kicking a target which was placed 28 inches ahead of the toe. Both hands and both feet were tested. Results revealed a tendency for a low, negative correlation, the average of all four movements being a non-significant r of -0.153.

Mendryk (52) studied RT - MT correlations in 150 subjects, who were divided into three age groups: 10 to 13 years, 19 to 25 years, and 40 - 55 years; for an 11-inch forward arm-thrust movement, as employed by Pierson (42) and Youngen (43). Another test used a 36-inch circular clockwise orbit of the hand in the horizontal plane. Neither of the two movements revealed any significant RT - MT correlations for any age group. In averaging the correlations of the three groups, for each movement, to obtain an over-all RT - MT correlation, it was found that neither relationship differed significantly from zero.

Clarke (16) measured 48 male university students in speed of reaction and movement of a horizontal, lateral-adductive arm movement of 117 cm. The resulting correlation was found to be non-significant ($r = 0.045$).

Henry (53), using a similar movement and similar equipment to Clarke (16), tested 120 male college students to establish a RT - MT relationship. The resulting relationship between RT and MT was found to be non-significant ($r = 0.016$).

Smith (54) measured the speed of reaction and movement in lateral, adductive and abductive, horizontal arm movements of 80 cm., as well as in forward and backward movements of the leg over a distance of 70 cm. Reliability coefficients were found to be relatively high but none of the obtained correlations between RT and MT was found to be statistically significant, falling between $r = 0.157$ and $r = -0.043$.

Henry (55) studied the reaction latency and time required for three arm movements made at maximal speed of 402 subjects, of both sexes and ages ranging from 8 - 30 years. Stimuli and movements were of varying types and complexity, but were found to have no influence on the RT - MT correlations. In all cases, the correlation between

RT and MT was found to be non-significant, varying between 0.113 and -0.124.

Clarke and Glines (19) studied 65 subjects in their speed of reaction and movement in two tests, and found a non-significant relationship between RT and MT. The first test involved a total body movement over a distance of ten feet and an arm movement a distance of 18 inches. The correlations were r = -0.20 and r = 0.10, respectively.

REFERENCES

1. Meisel, Stephen Gaylor, "The Effect of a Weight Training Program on the Speed of Running", microcards, Master of Science Thesis, Pennsylvania State University, 1957.

2. Pierson, William R., Rasch, Philip J., "Strength and Speed", Perceptual and Motor Skills, vol. 14 (1962), p. 144.

3. Chui, Edward, "The Effect of Systematic Weight Training on Athletic Power", Research Quarterly, vol. 21 (Oct. 1950), pp. 188 - 194.

4. Zorbas, William S., Karpovich, Peter V., "The Effect of Weight Lifting Upon the Speed of Muscular Contractions", Research Quarterly, vol. 22 (May 1951), pp. 145 - 149.

5. Wilkin, Bruce M., "The Effect of Weight Training on Speed of Movement", Research Quarterly, vol. 23 (Oct. 1952), pp. 361 - 369.

6. Masley, John W., Hairabedian, Ara, Donaldson, Donald N., "Weight Training in Relation to Strength, Speed and Co-ordination", Research Quarterly, vol. 24 (Oct. 1953), pp. 308 - 315.

7. DeLorme, Thomas L., Ferris, Benjamin G., Gallagher, J. Roswell, "Effect of Progressive Resistance Exercise on Muscle Contraction Time", Archives of Physical Medicine, vol. 33 (Feb. 1952), pp. 86 - 92.

8. Endres, John Paul, "The Effect of Weight Training Exercise upon the Speed of Muscular Movement", microcards, Master of Science Thesis, University of Wisconsin, 1953.

9. Kurt, Charles P., "The Effect of Weight Training on Hand-Eye Coordination, Balance and Response Time", microcards, Master of Arts Thesis, State University of Iowa, 1953.

10. Meadows, Paul Eugene, "The Effect of Isotonic and Isometric Muscle Contraction Training on Speed, Force, and Strength", microcards, Doctor of Philosophy Dissertation, University of Illinois, 1959.

11. Clarke, David., Henry, Franklin M., "Neuromotor Specificity and Increased Speed from Strength Development", Research Quarterly, vol. 32 (Oct. 1961), pp. 315 - 325.

12. Rasch, Philip J., "Relationship of Arm Strength, Weight and Length to Speed of Arm Movement", Research Quarterly, vol. 25 (Oct. 1954), pp. 328 - 332.

13. Glines, Don, "Relationship of Reaction, Movement and Completion Times to Certain Motor, Strength, Anthropometric and Maturity Measures", microcards, Doctor of Philosophy Dissertation, University of Oregon, 1960.

14. Henry, F.M., Whitley, J.D., "Relationships Between Individual Differences in Strength, Speed and Mass in an Arm Movement", Research Quarterly, vol. 31 (Mar. 1960), pp. 24 - 33.

15. Henry, Franklin M., "Factorial Structure of Speed and Static Strength in a Lateral Arm Movement", Research Quarterly, vol. 31 (Oct. 1960), pp. 440 - 447.

16. Clarke, David H., "Correlation Between the Strength/Mass Ratio and the Speed of an Arm Movement", Research Quarterly, vol. 31 (Dec. 1960), pp. 570 - 574.

17. Smith, Leon E., "Individual Differences in Strength, Reaction Latency, Mass and Length of Limbs and their Relation to Maximal Speed of Movement", Research Quarterly, vol. 32 (May 1961), pp. 208 - 220.

18. Henry, Franklin M., Lotter, Willard S., Smith Leon E., "Factorial Structure of Individual Differences in Limb Speed, Reaction and Strength" Research Quarterly, vol. 33 (Mar. 1962), pp. 70 - 84.

19. Clarke, H. Harrison, Glines, Don, "Relationships of Reaction, Movement and Completion Times to Motor, Strength, Anthropometric and Maturity Measures of 13-year Old Boys, Research Quarterly, vol. 33 (May 1962), pp. 194 - 201.

20. DeLorme, Thomas L., "Restoration of Muscle Power by Heavy-Resistance Exercises", Journal of Bone and Joint Surgery, vol. 27 (Oct. 1945), pp. 645 - 667.

21. DeLorme, Thomas L., "Heavy Resistance Exercises", Archives of Physical Medicine", vol. 28 (Oct. 1946), pp. 607 - 630.

22. DeLorme, Thomas L., Watkins, Arthur, L., "Technics of Progressive Resistance Exercise", Archives of Physical Medicine, vol. 29 (May 1948), pp. 263 - 273.

23. DeLorme, Thomas L., Schwab, Robert S., Watkins, Arthur L., "The Response of the Quadriceps Femoris to Progressive-Resistance Exercises in Poliomyelitis Patients", Journal of Bone and Joint Surgery, vol. 30 - A (Oct. 1948), pp. 834 - 847.

24. Krusen, Edward M., "Functional Improvement Produced by Resistive Exercise of Quadriceps Muscles Affected by Poliomyelitis", Archives of Physical Medicine, vol. 30 (May 1949), pp. 271 - 277.

25. Gallagher, J. Roswell, DeLorme, Thomas L., "The Use of the Technique of Progressive-Resistance Exercise in Adolescence", Journal of Bone and Joint Surgery, vol. 31 - A (Oct. 1949), pp. 847 - 858.

26. McGovern, Richard E., Luscombe, Harold B., "Useful Modifications of Progressive Resistive Exercise Technique", Archives of Physical Medicine, vol. 34 (Aug. 1953), pp. 475 - 477.

27. Clarke, David H., Herman, Edward L., "Objective Determination of Resistance Load for Ten Repetitions Maximum for Quadriceps Development", Research Quarterly, vol. 26 (Dec. 1955), pp. 385 - 390.

28. Barney, Vermon S., "A Comparison of the DeLorme Technique of Progressive Resistance Exercise with a Modified Technique", microcards, Master of Science Thesis, Brigham Young University, 1956.

29. Barney, Vermon S., Bangerter, Blauer L., "Comparison of Three Programs of Progressive Resistance Exercise", Research Quarterly, vol. 32 (May 1961), pp. 138 - 146.

30. Hettinger, Theodor L., Müller, Erich A., "Muskelleistung and Muskeltraining", Arbeitphysiologie, vol. 15 (1953), pp. 111 - 126.

31. Steinhaus, Arthur H., "Strength from Morpurgo to Müller - A Half Century of Research", Journal of the Association for Physical and Mental Rehabilitation, vol. 9 (Sept. - Oct. 1955), pp. 147 - 150.

32. Müller, Erich A., "The Regulation of Muscular Strength", Journal of the Association for Physical and Mental Rehabilitation, vol. 11 (Mar. - Apr. 1957), pp. 41 - 47.

33. Müller, Erich A., "Training Muscle Strength", Ergonomics, vol. 2 (Feb. 1959), pp. 216 - 222.

34. Hettinger, Theodor, Physiology of Strength, Charles C. Thomas Publisher, Springfield, Ill., 1961.

35. Lawrence, Mary S., "Strengthening the Quadriceps: Progressively Prolonged Isometric Tension Method", The Physical Therapy Review, vol. 36 (Oct. 1956), pp. 658 - 661.

36. Rose, Donald L., Radzyminski, Stanley F., Beatty, Ralph R., "Effect of Brief Maximal Exercise on the Strength of the Quadriceps Femoris", Archives of Physical Medicine, vol. 38 (Mar. 1957), pp. 157 - 164.

37. Rose, Donald L., "Brief Maximal Isotonic Exercises in the Treatment of Knee Injuries", Journal of American Medical Association, vol. 171 (Nov. 1959), pp. 1673 - 1675.

38. Lawrence, Mary S., McGrail, Judith A., "Strengthening the Quadriceps Femoris: Progressive Weighted Isometric Exercise Method", The Physical Therapy Review, vol. 40 (Aug. 1960), pp. 577 - 584.

39. Gersten, Jerome W., "Isometric Exercises in the Paraplegic and in the Patient with Weaknesses of Quadriceps and Ham-strings", Archives of Physical Medicine and Rehabilitation, vol. 42 (1961), pp. 498 - 506.

40. Lawrence, Mary S., Meyer, Harriet R., Matthews, Nancy C., "Comparative Increase in Muscle Strength in the Quadriceps Femoris by Isometric and Isotonic Exercise and Effects on the Contralateral Muscle", Journal of the American Physical Therapy Association, vol. 42 (Jan. 1962), pp. 15 - 20.

41. Schweid, Daniel, Vignos, Paul J., Archibald, Kenneth C., "Effects of Brief Maximal Exercise on Quadriceps Strength In Children", American Journal of Physical Medicine, vol.41 (Oct. 1962), pp. 189 - 197.

42. Pierson, William R., "The Relationship of Movement Time and Reaction Time from Childhood to Senility", Research Quarterly, vol. 30 (May 1959), pp. 227 - 231.

43. Youngen, Lois J., "A Comparison of Reaction and Movement Times of Women Athletes and Nonathletes", Research Quarterly, vol. 30 (Oct. 1959), pp. 349 - 355.

44. Fairclough, Richard H., "Transfer of Motivated Improvement in Speed of Reaction and Movement", Research Quarterly, vol. 23 (March 1952), pp. 20 - 27.

45. Slater-Hammel, Arthur T., "Reaction Time and Speed of Movement", Perceptual and Motor Skills Research Exchange, vol. 4 (1952), pp. 109 - 113.

46. Henry, Franklin M., "Independence of Reaction and Movement Times and Equivalence of Sensory Motivators of Faster Response", Research Quarterly, vol 23 (Mar. 1952), pp. 43 - 53.

47. Howell, Maxwell, L., "Influence of Emotional Tension on Speed of Reaction and Movement", Research Quarterly, vol. 24 (Mar. 1953), pp. 22 - 32.

48. Pierson, William R., "Comparison of Fencers and Nonfencers by Psychomotor, Space Perception and Anthropometric Measures", Research Quarterly, vol. 27 (Mar. 1956), pp. 90 - 96.

49. Cooper, John H., "An Investigation of the Relationship between Reaction Time and Speed of Movement", microcards, Doctor of Physical Education Dissertation, Indiana University, 1956.

50. Wilson, Don J., "Quickness of Reaction and Movement Related to Rhythmicity or Nonrhythmicity of Signal Presentation", Research Quarterly, vol. 30 (Mar. 1959), pp. 101 - 109.

51. Lotter, Willard S., "Interrelationships Among Reaction Times and Speeds of Movement in Different Limbs", Research Quarterly, vol. 31 (May 1960), pp. 147 - 155.

52. Mendryk, Stephen, "Reaction Time, Movement Time, and Task Specificity Relationships at Ages 12, 22, and 48 Years", Research Quarterly, vol. 31 (May 1960), pp. 156 - 162.

53. Henry, Franklin M., "Reaction Time - Movement Time Correlations", Perceptual and Motor Skills, vol. 12 (Feb. 1961), pp. 63 - 66.

54. Smith, Leon E., "Reaction Time and Movement Time in Four Large Muscle Movements", Research Quarterly, vol. 32 (Mar. 1961), pp. 88 - 92.

55. Henry, Franklin M., "Stimulus Complexity, Movement Complexity, Age, and Sex in Relation to Reaction Latency and Speed in Limb Movements", Research Quarterly, vol. 32 (Oct. 1961), pp. 353 - 366.

CHAPTER III

METHODS AND PROCEDURE

Apparatus. The MT and RT testing apparatus was set on a 4-inch platform (See Fig. II).. Extending up at right angles from the sides of the base were two panels of plywood, approximately 18 inches apart. At the far end of the apparatus, away from the subject, was another panel of plywood. Two lights were placed on the top of this end panel, the light on the subject's left serving as a warning light, the other light as a stimulus light. The side panels contained the four timing stations which were placed at 17 degree intervals on a radius of 19 inches from the medial condyle of the subject's right knee.

The timing stations each consisted of a Texas Instrument H-35 photoconductive cell. The light and lens were mounted on the right panel and the cell on the left panel. The leg, as it swung through the prescribed arc, would break the circuit stopping the attached chronoscope. The cells were re-activated by pressing the reset button, located on the control panel.

The section described above will be known as the MT section. Connected to the bottom of each side of this section was a steel bracket, with a 5/16-inch hole, through which a ¼-inch steel rod, or track passed. The track was bolted to the base. When the front, or far end of the apparatus, was lifted up, this section of the apparatus could be moved along the track. When resting on the track, the angled lower part of the bracket "bit" into the track so that further movement was not possible.

The RT mechanism was mounted solidly on the end of the base closest to the subject. The movable part of the apparatus was placed so

FIGURE I. The RT and MT Testing Apparatus

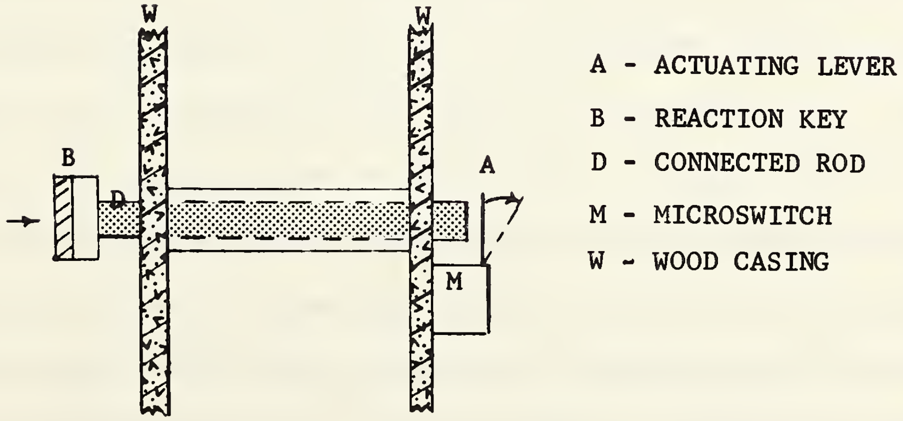

FIGURE II. The Reaction Time Mechanism

that the distance from the front of the subject's ankle to the first timing station was equal to the distance between each timing station. Since a gap between the two sections would inhibit movement of the foot, a sheet of heavy aluminum was permanently fastened to the RT section in such a way as to cover the gap but still allow movement of the MT section.

The reaction key was a circular piece of steel, approximately three inches in diameter, covered by rubber, ¼-inch thick, to prevent the subject's foot from slipping off the key. Welded to the back of the reaction key was a ½-inch rod which was guided to a microswitch through a piece of tubing (See Fig. II). When the reaction key was pressed, the connected rod was pushed back to depress the 3-inch metal actuating lever of a Honeywell Standard microswitch, of the single pull, double-throw type. When the stimulus light flashed and the reaction key was depressed, the circuit was complete, causing the RT chronoscope to operate. Release of the reaction key would break the circuit, stopping the reaction time chronoscope. Release of the key also allowed the actuating lever of the microswitch to move forward, which completed another circuit and started operation of the four MT chronoscopes. The differential travel of the microswitch lever could be set between .007 to .050 inches, with an over-travel of .020 inches. The error between stopping the RT chronoscope and starting the MT chronoscopes was found to be .005 seconds. It was decided that the error of the differential travel would be less than that of subtracting the reaction time from the completion time, or the time taken to complete the whole movement.

The bulbs used in the warning and stimulus lights were GE-NE45,

three-watt neon bulbs. Use of the neon bulb served to reduce error in timing in comparison to the flashlight or incandescent bulb. The latter type introduces a variable error due to the length of time required for the filament to warm up. As the bulb becomes warmer the filament requires less time to warm up, thus introducing an uncontrollable error (1).

The subject sat on a bench which was adjusted to fit the length of his lower leg (See Fig. III). In order to be able to withstand breaking from any sudden, hard movement by the subject, the bench top was made of a heavy plywood, 56 inches long by 30 inches wide. The wooden legs, 3 inches by 6 inches and 54 inches long, were diagonally supported, pivoted at the center around a 30-inch long piece of piping. The height of the bench could be adjusted at the back by turning the wheel of a screw-type manual worm jack. The front of the bench top was hinged to the legs, allowing the back legs to slide along the bottom of the top when being adjusted.

The Timing Apparatus. The timing equipment was mounted on a separate control panel (See Fig. IV) so that it could be moved away from the subject, possibly even to another room, in order to eliminate any sound cues that might be used by the subject as a warning. The chronoscopes used were five Standard S-1 Electric Chronoscopes, as described by Henry (1). According to Henry, these chronoscopes have an accuracy within ± 5/100 second. Upon testing these chronoscopes, it was calculated that the error was also approximately .005 seconds. The control panel also contained switches controlling the warning and stimulus lights plus a time delay thyratron timer. The wiring circuit for the control panel may be seen in Fig. V.

When the main switch was pushed forward and the stimulus light

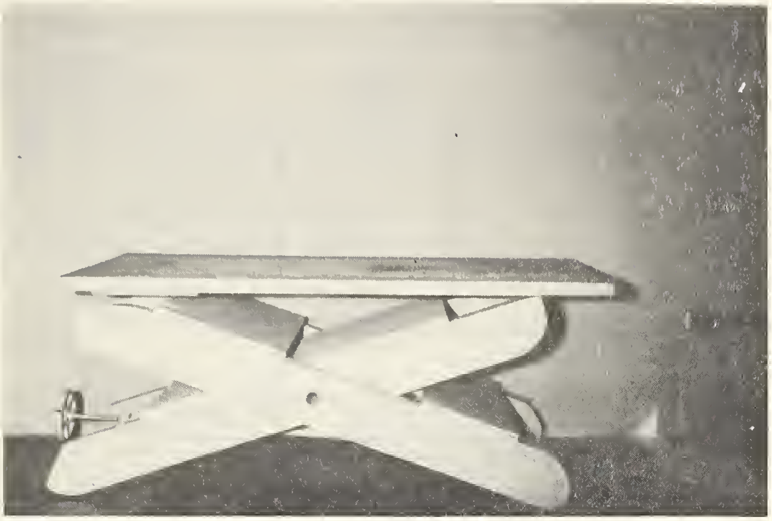

FIGURE III. The Adjustable Bench

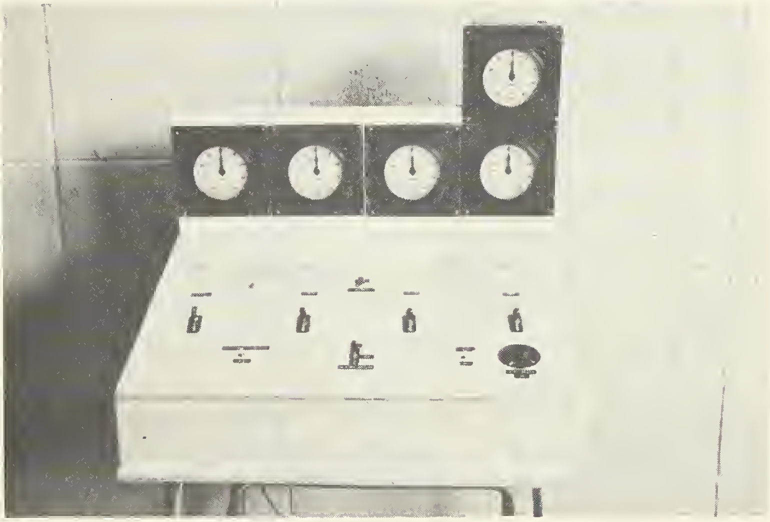

FIGURE IV. The Control Panel with Chronoscopes and Thyratron Timing Device

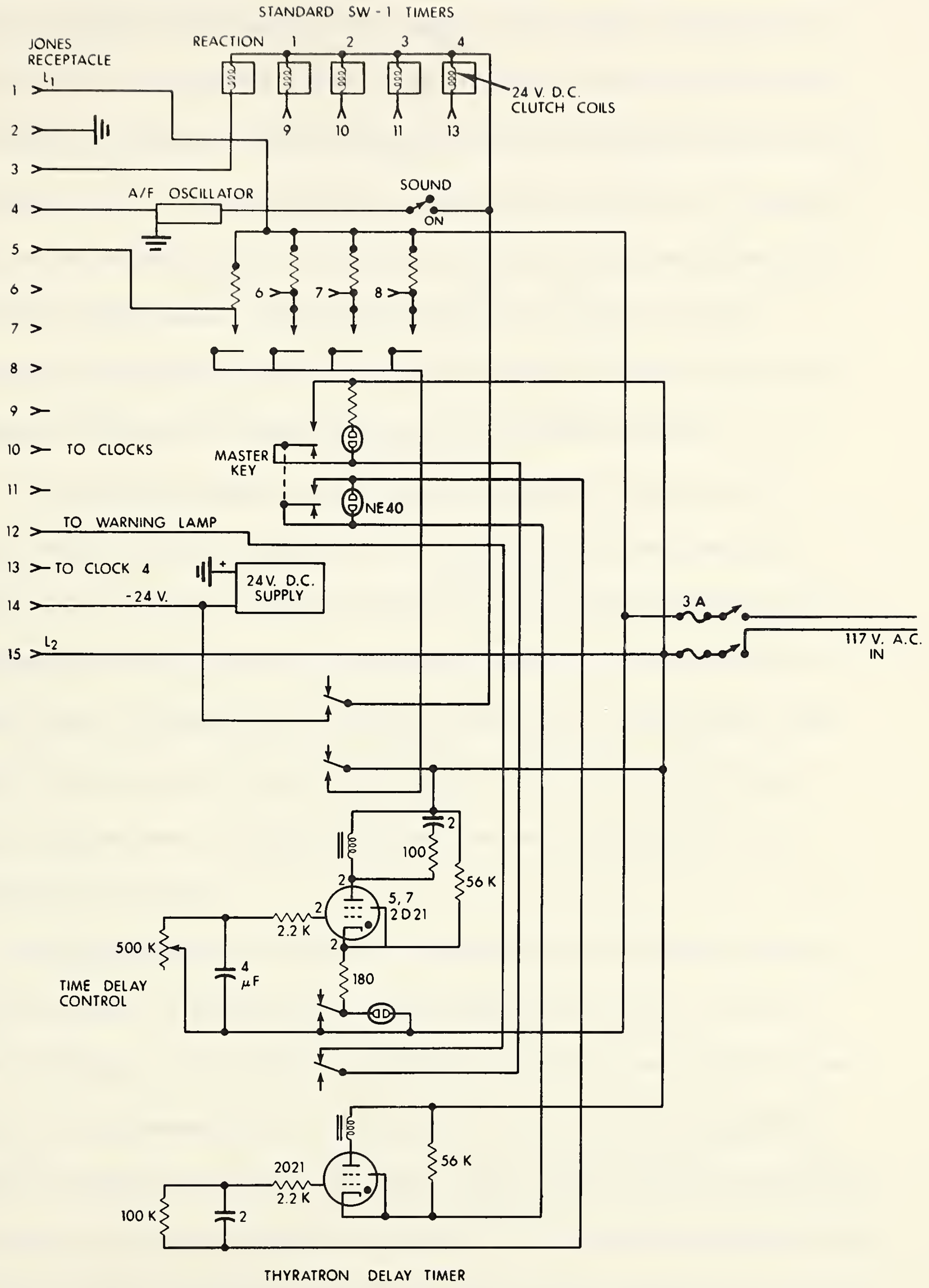

FIGURE V. Control Panel Circuit Diagram

switch was in the "on" position, the warning light on the testing apparatus flashed, followed by the stimulus light, after a delay of 1 - 4 seconds. The thyratron timer was a gas filled tube which was used to vary the interval between illumination of the warning light and the stimulus light, thus preventing the subject from reacting too soon and not to the stimulus light. Accuracy of the time delay was found to be within ± 1/100 second, using the 60 cycle A.C. electric current. Greater accuracy would have been gained through the use of D.C. current but this was not feasible because of the added expense.

As previously stated, one chronoscope recorded the length of time required for the reaction and the other four chronoscopes recorded the speed of movement at each of the four timing stations. Illumination of the stimulus light started operation of the RT chronoscope, which stopped when the subject released the reaction key, and the MT chronoscopes started upon release of this key. Each chronoscope stopped when the photo-electric beam was broken by the foot, breaking the circuit.

The Stopping Bar. To prevent hyperextension of the knee on the follow-through, a padded iron bar was placed at the top of the movement apparatus. Iron posts were bolted to the floor and braced to the back wall, approximately two feet apart, in order that the apparatus could be placed between the two posts. Holes were drilled in the sides of each post, approximately one inch apart, so that the horizontal stopping bar could be placed at various levels. This stopping bar was well-

padded with poly-vinyl protective material to prevent injury to the foot when it hit the bar. The bar was placed at a height sufficient to permit no more than an 80 degree swing of the leg. Thus any injury to the subject's knee from hyperextension was prevented. This assured a truer speed of movement as the subject could move his lower leg as quickly as possible with no fear of injury. The possibility of terminating the movement before completion was thus avoided.

The Subjects. The 45 subjects used in this study were male student volunteers from the University of Alberta, in Edmonton. Their ages ranged from 18 to 22 years, the mean age being 18.77 years. Since the university students were the most accessible, and since most of the previous studies on RT and MT were done on university students, it was decided to delimit this study to this group. Each subject involved in the study took part in no organized activities, other than his physical education classes, twice a week or in irregular recreation.

Each person was required in the laboratory four times per week for a total of five weeks. The subjects were equated on mean movement time with two others and randomly placed into one of three groups, a control group and two experimental groups.

The Testing Procedure. When the subject came for his initial meeting, he was shown the testing equipment and the testing movement was demonstrated twice for him. He was told that the stopping bar was to prevent injury to his knee from hyperextension. The experimenter then kicked the bar a number of times to demonstrate that there was no fear

of being injured from hitting the bar too hard. The subject then kicked the bar three times for his own reassurance. Then the subject was given standardized instructions after which he took three familiarization trials. The standardized instructions were as follows:

> This equipment is used to measure the length of time it takes you to react to a stimulus and to fully extend your knee. The light on the left will flash; this is the warning light which tells you that the stimulus light will appear after a brief interval. When this stimulus light flashes, simply extend your leg as quickly as plssible. The time delay between the warning and stimulus lights will not be constant. Remember you are to watch for the flash of the light on your left as the warning light and react to the light on your right. Do not move until you see the stimulus light flash.

The subject then took 20 trials, the last 15 being used in the statistical analysis. The only rest the subject received was the length of time required to record the times on the five chronoscopes and to return the chronoscopes to the starting position.

The testing procedure was carried on at the first meeting and a week later at the second meeting. Reliability was determined from the results of these two testing sessions. In the second session, the mean of the movement times of the last 15 trials was computed and the subjects were equated in groups of three on the basis of the mean of the movement. Each subject was assigned to a group by drawing a number from a hat.

The subjects were tested in a similar manner after 2½ weeks and at the end of the fifth week. They were tested on the same day as the first test and the time of day was approximated as closely as possible for each testing session.

<u>Strength Testing</u>. At the end of each testing session the subject's

strength was determined by the cable tensiometer method. During the Second World War, while serving in the Physical Reconditioning Branch of the Army Air Force, Clarke and Peterson (2) developed the cable tension tests to measure the strength of affected muscle groups in orthopedic disabilities. The tensiometer was originally designed to measure the tension of aircraft control cables, determining cable tension by measuring the force required to create offset (on riser) in the cable between two set points, the sectors (See Fig VI). The tension recorded on the dial was then converted into pounds from a calibration chart.

Clarke (3) compared four muscle strength recording instruments: the cable tensiometer, the Walkim-Porter strain guage, the spring scale and the Neuman myometer. He found that the cable tensiometer was the more consistent instrument for the six strength items tested, and was less sensitive to room changes. He found that the objectivity coefficients for the cable tensiometer varied between .90 and .95, having a consistently higher precision than that of the other instruments.

In a previous article, Clarke (4) carried out a study on the selection of proper joint angles and the location of strap positions in using cable tension methods for strength measurement of various parts of the body. His final directions for measurement of the knee extension were (4:415):

Starting Position

a. Subject in sitting, backward-leaning position; legs hanging free; arms extended to the rear, hands grasping sides of table.
b. Thigh adducted at hip joint to 180 degrees.
c. Knee in 115 degrees extension.

FIGURE VI. The Cable Tensiometer

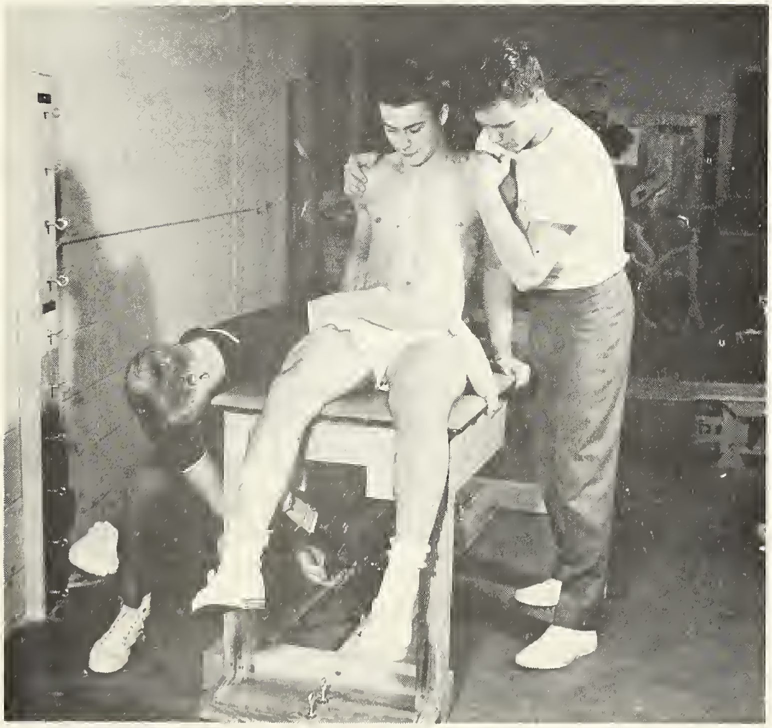

FIGURE VII. Quadriceps Strength Testing

Attachments

a. Centre of strap around leg midway between knee and ankle joints.

b. Cable attached to rear must hook at lower end of table.

Direction of Pull: Parallel with median line.

Precautions

a. Prevent lifting buttocks.

b. Prevent flexion of arms.

Objectivity Coefficient: 0.94

The subjects were tested on a treatment table or plinth (See Fig. VII). The strap was placed on the limb at the proper position, and a 1/16-inch cable, approximately 18 inches in length, stretched from the strap to a chain. The subject held his leg in the proper position while the examiner determined the correct knee joint angle and the proper length of the chain. The subject then relaxed his leg while the examiner anchored the chain to the proper hook under the table so that the strap was at right angles to the limb. Then the subject extended his knee as far as possible. The examiner retested the knee angle. While an assistant pressed down on the subject's thighs and the subject extended his knee fully, the examiner placed the tensiometer on the cable. The subject was then instructed to extend his knee as hard as possible. Clarke (5) stressed that an assistant should press down on the subject's thighs to prevent him from extending his hip, using it as a lever. Strength of the knee extension was tested at 115 degrees. Clarke (4) conducted a study to decide upon the joint angle for optimum strength measurement. After testing at 135 degrees and 115 degrees flexion, he decided upon the latter as the optimum angle. Three

measurements were taken, the highest reading being used as the strength measurement.

The Training Program. Both the isotonic and isometric exercise programs were conducted on a quadriceps table, as used by Richardson (12). The table consisted of a padded top, 30 inches square, supported by chrome legs 30 inches in height (See Fig. VIII). A nylon safety belt was attached to each side of the table to hold the subject's thighs to the bench, thus preventing additional leverage from hip extension.

Attached to the front right corner was a hollow aluminum tube which held the training arms (See Fig. VIII). The training arm consisted of two steel arms, 18 inches in length; each arm had an adjustable post at the bottom. One arm was on the outside of the bench so that the weights could be placed on the post, while the other arm was on the inside so that the subject could push against the padded post while doing his exercises.

The two arms rotated on a circular metal plate. A series of 5/16-inch holes was around the circumference of the plate, approximately one inch from the edge. A pin was pushed through the holes in the arms and circular plate to hold the arm in place for the isometric exercises.

Isometric exercises were conducted at three different angles: 115 degrees, 135 degrees and at 155 degrees. The subject sat down on the bench, and the thighs were strapped down. The arm was set at 115 degrees and the pin set in place. The subject extended his knee against the bar and on the command extended the knee as hard as possible for six seconds. At the end of six seconds the arm was moved up to 135 degrees,

FIGURE VIII. Quadriceps Training Table

when the subject once again performed a six-second maximal contraction. The arm was then moved up to 155 degrees where the subject extended his leg fully for a six-second maximal contraction.

The isotonic exercise program was similar to that used by Richardson (12). The maximum weight that could be lifted in a full extension of the knee was determined for each subject, this weight being known as 1 R.M., or one maximal repetition (13). As was done by Rose, et al (14), an attempt was made to add 1¼ pounds at each training session. If the subject could not possibly lift this added weight, it was removed from the post and the subject lifted the same weight as in the previous day.

When the subject reported for each training session, he sat on the bench with the thighs strapped down. The proper number of weight plates were placed on the post and the subject lifted them by extending his knee fully. A metronome was started so that the subject took six seconds to fully extend his knee, where the experimenter removed the weight allowing the subject to return his knee to the starting position. After a ten-second rest the subject again extended his knee in six seconds, the experimenter removing the weight at full extension. This was repeated for the third time after a 20-second rest.

Both groups trained once daily, four days per week for the five weeks' duration of the study.

Therefore, in summary, the testing procedure was as follows:

1. The subject reported to the laboratory where the equipment was demonstrated for him. The subject then performed 20 trials on the

RT - MT equipment. Effective leg strength was also determined.

2. One week later, the subject was again tested for speed of reaction and movement. The mean of the last 15 of 20 trials of total movement time was calculated and the subjects were equated in groups of three, each being placed into one of three groups: a control or one of two experimental groups. Strength was again measured to determine the reliability of measurement.
3. Each subject in either experimental group reported four times a week, during the five weeks of the study, to perform the prescribed isotonic or isometric exercises.
4. The subject was again tested for speed of movement and reaction, as well as for strength, after two and one-half weeks of training and at the end of the training program.

REFERENCES

1. Henry, Franklin M., "Precision and Operation of the Hundredth-Second Electric Timer", Research Quarterly, vol. 30 (Mar. 1959), pp. 117 - 121.

2. Clarke, H. Harrison, Peterson, Kjell J., "Strength Tests of Affected Muscle Groups Involved In Orthopedic Disabilities", Unpublished manuscript, Springfield College, Springfield, Mass., 1945.

3. Clarke, H. Harrison, "Comparison of Instruments for Recording Muscle Strength", Research Quarterly, vol. 25 (Dec. 1954), pp. 398 - 411.

4. Clarke, H. Harrison, "Improvement of Objective Strength Tests of Muscle Groups by Cable-Tension Methods", Research Quarterly, vol. 21 (Dec. 1950), pp. 399 - 419.

5. Clarke, H Harrison, A Manual: Cable-Tension Strength Tests, Chicopee, Mass., Brown-Murphy Co., 1953.

6. Henry, F.M., Whitley, J.D., "Relationships Between Individual Differences in Strength, Speed, and Mass in an Arm Movement", Research Quarterly, vol. 31 (Mar. 1960), pp. 24 - 33.

7. Henry, Franklin M., "Factorial Structure of Speed and Static Strength in a Lateral Arm Movement", Research Quarterly, vol. 31 (Oct. 1960), pp. 440 - 447.

8. Clarke, David H., "Correlation Between the Strength/Mass Ratio and the Speed of an Arm Movement", Research Quarterly, vol. 31 (Dec. 1960), pp. 570 - 574.

9. Smith, Leon E., "Individual Differences in Strength, Reaction Latency, Mass and Length of Limbs, and their Relation to Maximal Speed of Movement", Research Quarterly, vol. 32, (May 1961), pp. 208 - 220.

10. Clarke, David H., Henry, Franklin M., "Neuromotor Specificity and Increased Speed from Strength Development", Research Quarterly, vol. 32 (Oct. 1961), pp. 315 - 325.

11. Henry, Franklin M., Lotter, Willard S., Smith, Leon E., "Factorial Structure of Individual Differences in Limb Speed, Reaction and Strength", Research Quarterly, vol. 33 (Mar. 1962), pp. 70 - 84.

12. Richardson, John, "The Effect of Brief Isometric and Isotonic Exercise Programmes on the Development of Strength and Muscular Endurance", Unpublished Master of Science Thesis, University of Alberta, 1963.

13. DeLorme, Thomas L., "Restoration of Muscle Power By Heavy-Resistance Exercises", Journal of Bone and Joint Surgery, vol. 27 (Oct. 1945), pp. 645 - 667.

14. Rose, Donald L., Radzyminski, Stanley F., Beatty, Ralph R., "Effect of Brief Maximal Exercise on the Strength of the Quadriceps Femoris", Archives of Physical Medicine and Rehabilitation, vol. 38 (1957), pp. 157 - 164.

CHAPTER IV

RESULTS AND DISCUSSION

Results

Reliability of Measurements. The Pearson Product-Moment method (1:92) was used to determine the test-retest reliability coefficients for all the measurements used in the study. The second test was administered exactly one week after the first test, at the same time of day and on the same day. The odd-even method of calculating reliability, as recommended by Henry (2), was also determined for the RT and MT scores. These were determined to test for individual differences in the testing and were computed on Test 1. The obtained reliability coefficients appear in Table I. All were significantly different than zero at the .01 level of confidence (N = 45).

Table I

Test-Retest Reliability Coefficients

Variable	N	Reliability Product-Moment	Odd-Even
Speed of Movement	45	0.86[a]	0.979[a]
Reaction Time	45	0.62[a]	0.954[a]
Strength	45	0.84[a]	_____

[a] Statistically significant at the .01 level of confidence.

Measurements of Movement Time (MT). The experimental groups I (isometric) and II (isotonic), and the control group III were equated on the basis of speed of movement on the initial test. The means for the groups were 0.1303, 0.1304 and 0.1297, respectively. A one-way

analysis of variance computed to determine any significant differences between the groups on their initial performance, revealed an F of 0.00. This was below that required for significance at the .05 level of confidence.

The next test for MT (test 2) was administered after 2½ weeks of training, which was half-way through the training period. The Isometric training group, Group I, showed an average increase in mean MT of 0.0019 seconds, a 1.46 per cent increase, while Group II decreased an average of 0.0004 seconds, or 0.31 per cent. Group III also increased an average of 0.0034 seconds or 2.62 per cent. None of these increases was found to be significant at the required .05 level of confidence. A one-way analysis of variance revealed no group differences (F =1.0).

At the conclusion of the training session the final test of MT was administered (test 3). All groups showed an average decrease in MT from test 2, none of which was found to be significantly different from zero.

In testing for significant gains in the three groups from test 1 to test 3, none was found to be significantly different from zero at the .05 level of confidence. Group II showed the largest average gain, or decrease in time in MT, but a test for significance showed no significant changes ($t = 0.042$) with 14 degrees of freedom. Since Group II showed the largest average change from test 1 to test 3 and the t-value failed to reach significance, it was not deemed necessary to perform any further tests of significance. The results are shown in Table II.

The mean changes in MT are shown in Figure IX.

Measurements of Reaction Time (RT). A one-way analysis of variance on the initial test revealed no differences in mean RT between Group I (0.2356), Group II (0.2339), or Group III (0.2429). The obtained F of 0.23 showed no group differences. Test 2 produced decreases in the average RT for all groups, none of which was significantly different from zero. Test 3 also produced decreases in average RT, but again none was found to be statistically different from zero. A one-way analysis of variance indicated no group differences at test 2.

Group II showed the largest decrease in average RT between test 1 and test 3. A test of significance revealed no significant changes in RT (t = 0.0028 with df = 14). Since this group had the largest average change and this was not significant, no further tests of significance were performed. The results are shown in Table II. A one-way analysis of variance indicated no group differences at test 2 (F = 1.30). The mean changes are demonstrated in Figure X.

Measurements of Strength. On the initial test of strength a one-way analysis of variance revealed no group differences (F = 0.61). At the time of testing, test 2 indicated significant increases in strength in both Group I and Group II. Group I gained an average of 31.00 pounds and Group II, 26.73 pounds, increases of 12.04 per cent and 10.67 per cent respectively. Tests of significance revealed that these strength increases were significantly different from zero at the .01 level of confidence (t's of 3.45 and 4.44, respectively).

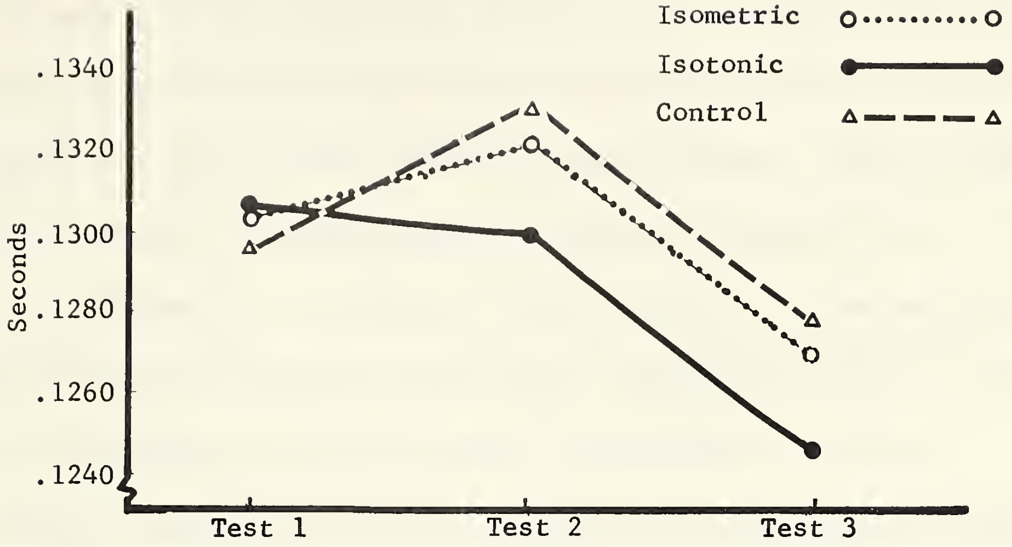

FIGURE IX. Mean Movement Times on Three Tests

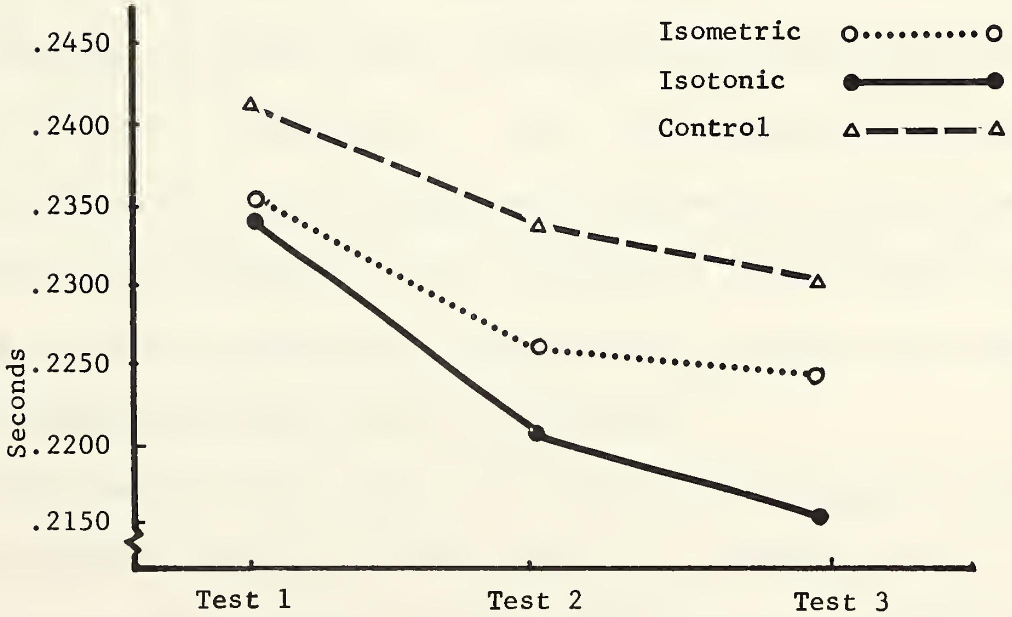

FIGURE X. Mean Reaction Times on Three Tests

However, an analysis of variance at test 2 revealed no group differences (F = 0.209).

In test 3, Group I gained in strength an average of 17.60 pounds and Group II an average of 24.93 pounds, increases of 18.9 per cent and 20.6 per cent respectively, from the initial measures. Both of these strength increases were significantly different from zero at the .01 level of confidence (t = 4.10 and t = 3.76 with df = 14, respectively). Group III showed an average increase of 6.7 pounds which was not statistically significant at the .05 level of confidence (t = 1.16).

Group I and Group II gained in strength an average of 48.6 pounds and 51.7 pounds, respectively, from test 1 to test 3. Both of these gains were statistically significantly different at the .01 level of confidence (t = 5.47 and t = 10.02, respectively). Group II had the largest overall increase in strength (See Fig. XI). Group III increased an average of 15.5 pounds, which was significantly different from zero at the .05 level of confidence (t = 2.35). The strength increases are shown in Table II. Tests of significance revealed that both experimental groups made significantly greater increases in strength than the control group (t's of 3.08 and 3.59, respectively), but there was no significant difference between the two former groups.

The isometric group, Group I, was split up into 3 groups of 5 with each subgroup training at the same angles but in a different order. One subgroup trained in the order 115, 135 and 155 degrees, the second at 155, 135 and 115 degrees and the third subgroup trained in the order 135, 115

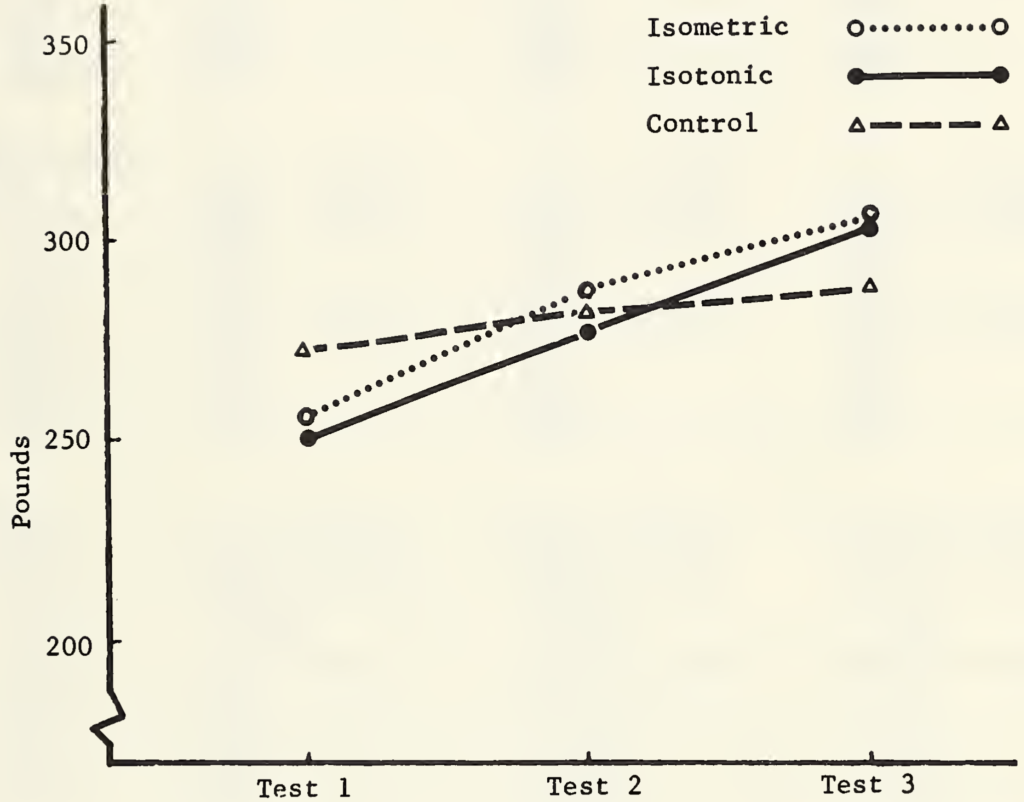

FIGURE XI. Mean Strength on Three Tests

TABLE II

Mean Gains in Movement Time,
Reaction Time and Strength.

	ISOMETRIC MEAN	SD	ISOTONIC MEAN	SD	CONTROL MEAN	SD
Movement Time						
Test 1	.1303	.0182	.1304	.0275	.1297	.0187
Test 2	.1322	.0151	.1300	.0194	.1331	.0171
Gain	-.0019		.0004		-.0034	
t12	NS		NS		NS	
Test 3	.1270	.0192	.1242	.0173	.1276	.0178
Gain	.0052		.0058		.0055	
t23	NS		NS		NS	
Gain	.0033		.0062		.0021	
t13	NS		.042		NS	
Reaction Time						
Test 1	.2356	.0390	.2339	.0398	.2429	.0241
Test 2	.2264	.0303	.2210	.0301	.2338	.0200
Gain	.0092		.0129		.0091	
t12	NS		NS		NS	
Test 3	.2247	.0307	.2151	.0308	.2310	.0217
Gain	.0017		.0059		.0028	
t23	NS		NS		NS	
Gain	.0109		.0188		.0119	
t13	NS		.028		NS	
Strength						
Test 1	257.40	57.95	250.47	61.19	272.80	48.57
Test 2	288.40	70.67	277.20	70.82	281.67	63.76
Gain	31.00		26.73		8.87	
t12	3.45[a]		4.44[a]		1.20	
Test 3	306	58.41	302.13	62.86	288.33	75.45
Gain	17.60		24.93		6.66	
t23	4.10[a]		3.76[a]		1.16	
Gain	48.60		51.66		15.53	
t13	5.47[a]		10.02[a]		2.35[b]	

[a] Statistically significant at .01 level of confidence ($t = 2.947$)

[b] Statistically significant at .05 level of confidence ($t = 2.131$)

NS Not statistically significant

and 155 degrees. The latter subgroup had the greatest over-all gains, which was an average increase of 18.4 pounds. The second subgroup showed an average increase of 17.8 pounds while the first subgroup only gained an average of 12.3 pounds.

Reaction Time - Movement Time Correlations. The RT and MT mean scores for each subject on the initial test were pooled to gain an over-all RT - MT correlation for 47 subjects. The correlation coefficient, as computed by the Pearson Product-Moment method, was found to be 0.538, which was statistically different from zero. Thirty-eight subjects were tested the second time for test-retest correlations and the combined RT - MT correlation was found to be 0.629, which was also statistically different from zero.

RT - MT correlations were computed at each timing station on the initial test for 47 subjects. They were 0.554, 0.571 and 0.633 for stations at 17, 34 and 51 degrees, respectively.

The RT - MT correlation of each separate group was then calculated and relatively high correlations were found for Group I and Group II at each testing session. In test 1 and test 3 the correlation coefficients for Group I were significantly different from zero at the .01 level of confidence (r = 0.673 and 0.849) while test 2 was statistically significant at the .05 level (r = 0.532). The RT - MT correlation coefficients for Group II were significantly different from zero at the .01 level of confidence on all three tests (r's of 0.805, 0.693 and 0.701 respectively). No correlations for Group III were significantly

different from zero (r's of 0.291, 0.070 and 0.134 respectively). These results are shown in Table III.

<u>Strength - Reaction Time Correlations</u>. The Pearson Product-Moment correlation coefficient for the pooled subjects on the initial test (N = 45) was found to be significantly different from zero at the .05 level of confidence (r =-0.357).

Separate group Strength - RT correlation coefficients were then computed for each of the three testing periods (See Table III). Group I showed no significant correlation coefficients at each of the three testing periods (r =-0.373, -0.214 and -0.322 respectively) as did Group II during testing periods 1 and 2 (r = -0.217, -0.420) and Group III during all testing periods (r = -0.172, -0.192 and 0.122 respectively). However, the obtained correlation coefficient of -0.503 for Group II, on test 3, was found to be significantly different from zero, at the .05 level of confidence.

<u>Strength - Movement Time Correlations</u>. On the initial test the Strength - MT correlation coefficient for the pooled groups was -0.504, which was significantly different from zero, at the .01 level of confidence (N = 45).

Separate group Strength - MT correlation coefficients were then computed for each of the three testing periods (See Table III). Group I showed no statistically significant correlation coefficients at each of the three testing periods (r = -0.475, -0.286 and -0.430, respectively). During testing periods 1 and 2, Group II showed correlation

TABLE III

Correlations Computed at Each Testing

Period for Each Group

Variables	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
RT - MT	.673[a]	.805[a]	.291	.532[b]	.693[a]	.070	.849[a]	.701[a]	.134
Strength-MT	-.475	-.618[a]	-.593[b]	-.286	-.676[b]	-.719[a]	-.430	-.404	-.530[b]
Strength-RT	-.373	-.217	-.172	-.214	-.420	-.192	-.322	-.503[b]	.122

[a] Statistically significant at the .01 level of confidence

[b] Statistically significant at the .05 level of confidence

coefficients which were significantly different from zero at the .01 level of confidence (r = -0.618 and -0.676), but no such statistically significant correlation on test 3 (r = -0.404). Group III showed statistically significant strength - MT correlations on all three tests. The observed correlation coefficients of -0.593 and -0.530 were significantly different from zero at the .05 level of confidence on tests 1 and 3 respectively, and -0.719 for test 2 was significantly different from zero at the .05 level of confidence.

Changes in Strength Correlated with Changes in Reaction Time. Changes in strength from test 1 to test 2 were correlated with changes in reaction time over the same period for all three groups. The correlation coefficients were -0.023, -0.215 and 0.362 respectively. Computed correlations of over-all strength changes with over-all changes in reaction time produced coefficients of 0.130, -0.142 and 0.431 respectively. None of these correlation coefficients was found to be statistically significant (See Table IV).

Changes in Strength Correlated with Changes in Movement Time. The changes in strength from test 1 to test 2 were correlated with that of movement time for each group, and were found to be -0.185, -0.111 and 0.352 respectively. Correlations of -0.392, -0.197 and -0.196 were found for each group for changes in strength and movement time from pretest to the final test. None of these correlation coefficients was found to be statistically significant (See Table IV).

TABLE IV

Correlation Coefficients for Changes in

Strength, Reaction Time and Movement Time.

Groups	Test 1 to Test 2	Test 1 to Test 3
Strength - RT		
Isometric	-0.023	0.130
Isotonic	-0.215	-0.142
Control	0.362	0.431
Strength - MT		
Isometric	-0.185	-0.392
Isotonic	-0.111	-0.197
Control	0.352	-0.196

Discussion

Reliability of Measurements. In a review of the related literature, many of the authors neglected to state the reliabilities of their measurements in their studies (3,4,5). The majority of the remaining literature comes from the University of California where Henry and his students (6, 7,8,9,10,11,12) have computed reliabilities using the odd-even method and correcting to full test by use of the Spearman-Brown formula. This method is based on a large number of trials administered at one testing period. Two sub-sets of data are derived: one using the even-numbered trials and the other being derived from the odd-numbered trials. The mean of the trials for each individual is developed for each sub-set and the result measures the variance of the individual in relation to the total variance of the group. A low variance

will yield a high reliability.

The odd-even reliability coefficients were calculated for comparative purposes to test any possible errors in the present test as well as to obtain the reliability of individual performance on that particular testing session. The observed reliability coefficients for RT, 0.954, and MT, 0.979, compare quite favourably with reported reliabilities (6,7,8,9,10,11). Henry (6) reported MT reliabilities between 0.96 and 0.98, whereas Clarke (7) found reliability coefficients of 0.893 for RT and 0.946 for MT. These are similar to the findings of Clarke and Henry (8) of 0.911 and 0.958 and Wilson (9) of 0.889 and 0.962 respectively, all of whom studied arm movements. In a test of a leg movement, such as that used in place-kicking in football, Lotter (10) found RT reliabilities between 0.913 and 0.934 and MT reliabilities between 0.847 and 0.963. Mendryk (11) found RT and MT reliabilities of an arm movement varying between 0.896 and 0.986.

Reaction time reliability coefficients, then, are lower than the reliability coefficients of speed of movement. The most likely explanation for this phenomenon is that the speed of reaction may be affected by psychological factors: the individual's mental set or the thought processes at that particular moment. These considerations might tend to vary within the individual and have more effect on how quickly the subject reacts rather than upon his speed of movement. The low test-retest reliability coefficient of 0.62 in the present study would attest to this when compared to the 0.86 reliability coefficient for

speed of movement. The fact that the two tests were administered 7 days apart would also tend to lower the reliability coefficients. A lengthy delay between testing sessions allows for changes in physiological and psychological conditions. The individual's internal and external conditions are not the same on the second test as on the first test.

The calculated test-retest reliability coefficient of 0.84 for strength seems to be low in comparison to that attained by Clarke (13), who reported an objectivity coefficient of 0.94. Three reasons for this are inexperience of the experimenter, possible apprehension of the subjects on the first testing occasion and learning on the part of the subjects. The latter two reasons would seem to be the most logical explanation for the low strength reliability coefficients as the standardized testing procedure was followed as closely as possible. Odd-even reliabilities were not calculated because of insufficient measures.

Measurements of Reaction and Movement Times. As stated in the results there were no statistically significant gains in reaction time and movement time after five weeks of training. The RT scores tended to gradually decrease, or show a tendency towards improvement, on each of the two final testing sessions, but no changes were found to be significantly different from zero. The isometric and control groups tended to be slower in speed of movement on the half-way test but all groups decreased in mean MT after five weeks of training. However, none of

these changes was found to reach statistical significance.

Clarke and Henry (8) also found no statistically significant gains in RT, but they did find that ten weeks of weight training improved the speed of a simple, basic arm movement, as did Chui (14) after three months of weight training and Masley, et al (15), after six weeks of weight training. Pierson and Rasch (16) found that four weeks of weight training produced statistically significant strength increases but had no effect upon the speed of reaction or arm extension; this coincides with the findings of the present study in that five weeks of strength training produced significant strength increases with no changes in speed of reaction and of a leg movement.

It may be noted that the isotonic group made the largest mean decreases in both RT and MT over the five-week period of training. Clarke and Henry (8) found a significant increase in MT after a ten-week period of general weight training. It may be hypothesized that had the present study been conducted for a period of ten weeks, significant gains might have been found. However, in Clarke and Henry's study the experimental group only trained twice a week whereas the isotonic group in the present study trained four times a week.

Measurements of Strength. Statistically significant increases in strength were found in both the isometric and isotonic groups at the half-way test, with average strength increases of 12.04 and 10.67 per cent, respectively. The control group showed no statistically significant strength increases. The final tests found that all three groups

increased significantly in strength. Groups I and II showed mean increases of 18.9 and 20.6 per cent respectively, while Group III showed an increase of 5.7 per cent. Both experimental groups were found to have made significantly greater strength increases compared to the control group, but there was no statistical significance between the two experimental groups.

In a study by Richardson (17), forty high school boys trained five times a week for five weeks, with a training procedure which paralleled that of the present study. His results also showed that both experimental groups made significantly greater strength increases than the control group. There was no statistically significant difference between the two experimental groups. Gersten (18) also found no differences in quadriceps strength between the isotonic and isometric training groups.

Petersen (19) reported finding no statistically significant strength increases in the quadriceps muscle from either 1 or 10 isometric contractions per day, after 20 to 36 days of training. The results of the present study would seem to contradict Petersen's findings as statistically significant isometric strength increases of 12 per cent were found after 2½ weeks of training and 19 per cent after 5 weeks of training with three six-second maximal contractions. In his discussion Petersen questions many previous studies which have reported significant increases; as the same instruments were used for training and strength testing, the increases could possibly be due to improvement

in skill in using the instrument or learning. Hettinger and Müller used the same instrument for both training and testing, and found significant isometric strength increases while Petersen used different instruments and found no significant strength increases. In the present study the subjects in the isometric training group trained on the quadriceps training table and were tested by the cable tensiometer. The results seem to verify the findings of Hettinger and Müller that isometric exercise causes significant increases in strength and contradict those of Petersen.

Group III in the present study, showed a strength increase which was statistically significant at the .05 level of confidence. On the initial test the control group had a higher mean strength than the other two groups. Four individuals, and two in particular, in the control group showed large average strength increases over the five-week training period. The individuals concerned were questioned regarding any extra physical activity, and the only explanation found was that they were walking to and from the campus and that they were also participating in beginner swimming classes. Using these previously inactive muscles may have caused the strength increases. The factor of learning how to extend the knee and pull properly might also have caused the increase in strength.

The findings in the control group tend to emphasize an important point: just what should a control group really do during the interval between testings? Ideally it is assumed that these individuals should participate in no regular, organized activity. The result would undoubtedly be that they would decrease in the independent variable, in this case strength. However, it is difficult and undesirable to have these individuals remain completely inactive for so long a period of

time.

Perhaps a more desirable method would be to have the individuals in the control group not remain inactive but to carry on with their usual activities, that is, they should not change their normal activities unless these are designed for body-building and muscle strengthening. Each individual should not attempt to learn something new that may involve the same muscle groups that are of concern in the study. In the case of the present study the individuals who made the largest gains were doing more walking than had been done previously and they were learning to swim. Some strokes involve the quadriceps muscle.

Reaction Time - Movement Time Correlations. No studies reviewed examined RT - MT correlation coefficients of the lower leg. Smith (21) found the RT - MT correlation coefficient to be 0.241 in swinging the full leg forward, but this failed to reach significance. Lotter (10) found non-significant negative correlations of -0.087 and -0.146 for the right and left legs respectively, in the same movement studied by Smith. In another movement of the full leg, Fairclough (22) also reported a non-significant negative correlation coefficient of -0.278. Hence, none of the above correlation coefficients is similar to the one found in the present study (0.538). Pierson (4) also found an RT - MT correlation coefficient of 0.55, but this was for a hand movement. The remainder of the related literature reported non-significant correlation coefficients or correlations of low significance, all being studies using arm movements. The positive correlation coefficient of 0.538 was verified by that computed on the second initial test (0.629), which had been taken for test-retest reliabilities (N = 38).

Originally the reaction key was designed to go back with the

weight of the subject's foot. However, it was found that the subject did have to exert some backward pressure to depress the key. Hence, there is a possibility that use of the antagonistic muscle to hold the reaction key back caused a change in the speed of reaction, which would have an effect on the RT - MT correlation coefficient.

Strength - Reaction Time and Strength - Movement Time Correlations. The pooled strength - reaction time correlation coefficient of r = -0.357 was found to be statistically significant at the .05 level of confidence. By squaring the reliability it is possible to attain a measure of the common variance (r^2 = 0.129). In this case only approximately 13 per cent of the variance in reaction time is accounted for by the variance in strength. Hence, the two factors of strength and reaction time may be considered to be independent of each other; strength has very little influence on an individual's speed of reaction.

When the subjects were divided into the three groups and strength - RT correlation coefficients were computed, none of the resulting coefficients was significantly different from zero. Similar results were found on test 2 and test 3, except for the isotonic group which showed a slightly significant correlation between the two factors. Hence, the two factors do not seem to be strongly related. Pierson and Rasch (16) found a non-significant correlation between strength and RT of r = -0.23

The significant strength - MT correlation coefficient is supported in part by Henry (6) who found statistically significant correlation coefficients of -0.36 and -0.34 for male and female subjects, respectively, on a horizontal adductive arm swing. Instead of using static strength he combined strength and arm weight to form a strength/mass

ratio which was correlated with speed of movement. In a similar type of study, using the same factors, Henry and Whitley (12) found non-significant correlation coefficients of -0.039 and -0.160. Although these results differ with the above results, they are supported by Clarke (7) who also found a non-significant relationship of -0.277 between the strength/mass ratio and speed of movement. Clarke and Henry (8) confirmed these findings with non-significant correlation coefficients of 0.034 and 0.163 between the strength/mass ratio and a speed score. When the MT was correlated with the S/M ratio the results were similar except they were negative. In correlating strength and speed of movement, Pierson and Rasch (16) found a non-significant correlation of r = -0.28. Of significance is the fact that Clarke (7) correlated static strength with MT and found a significant negative correlation coefficient of -0.369.

When the subjects were divided into the three groups, somewhat spurious correlation coefficients were obtained. These findings are difficult to explain except that the size of each group was not large enough to allow for stability of results.

An over-all examination of the results of this study and others seems to show that while an individual's strength and ability to move quickly are related, this relationship tends to be quite small.

<u>Correlation Between Changes in Strength, Speed and Reactions</u>. Again no studies have been conducted which attempt to find a correlation between changes in speed of reaction and strength. Hence, no comparisons can be made. In view of the findings that reaction time was not decreased after five weeks of strength training, it would not seem possible to find a significant correlation between changes in reaction time and changes in strength. This hypothesis is confirmed

by the results. Some of these correlation coefficients seem to be spurious which again is probably due to the small number of subjects in each group.

Clarke and Henry (8) found that individual changes in strength correlated with individual changes in speed ($r = 0.405$). The control group in his study exhibited a non-significant correlation coefficient of 0.203 which is similar to that of Group III ($r = -0.196$) in the present study. Neither of the two experimental groups showed a significant correlation between changes in strength and changes in speed of movement, which is contrary to that found by Clarke and Henry. Again, since there were no decreases in speed of movement over the entire training period, it would not be expected that there would be any significant correlation between changes in speed of movement and changes in strength.

REFERENCES

1. Ferguson, George A., Statistical Analysis in Psychology and Education, McGraw-Hill Book Co., Inc., Toronto, 1959.

2. Henry, Franklin M., "Reliability, Measurement Error, and Intra-Individual Difference", Research Quarterly, vol. 30 (1959), pp. 21 - 24.

3. Pierson, William R., "The Relationship of Movement Time and Reaction Time from Childhood to Senility", Research Quarterly, vol. 30 (1959), pp. 227 - 231.

4. Youngen, Lois J., "A Comparison of Reaction and Movement Times of Women Athletes and Nonathletes", Research Quarterly, vol. 30 (1959), pp. 349 - 355.

5. Slater - Hammel, Arthur T., "Reaction Time and Speed of Movement", Perceptual and Motor Skills Research Exchange, vol. 4 (1952), pp. 109 - 113.

6. Henry, Franklin M., "Factorial Structure of Speed and Static Strength in a Lateral Arm Movement", Research Quarterly, vol. 31 (1960), pp. 440 - 447.

7. Clarke, David H., "Correlation Between the Strength/Mass Ratio and the Speed of an Arm Movement", Research Quarterly, vol. 31 (1960), pp. 570 - 574.

8. Clarke, David H., Henry, Franklin M., "Neuromotor Specificity and Increased Speed from Strength Development", Research Quarterly, vol. 32 (1961), pp. 315 - 325.

9. Wilson, Don J., "Quickness of Reaction and Movement Related to Rhythmicity or Nonrhythmicity of Signal Presentation", Research Quarterly, vol. 30 (1959), pp. 101 - 109.

10. Lotter, Willard S., "Interrelationships Among Reaction Times and Speeds of Movement in Different Limbs", Research Quarterly, vol. 31 (1960), pp. 147 - 155.

11. Mendryk, Stephen, "Reaction Time, Movement Time and Task Specificity Relationships at Ages 12, 22 and 48 years", Research Quarterly, vol. 31 (1960), pp. 156 - 162.

12. Henry, Franklin M., Whitley, J.D., "Relationships Between Individual Differences in Strength, Speed and Mass in an Arm Movement", Research Quarterly, vol. 31 (1960), pp. 24 - 33.

13. Clarke, H. Harrison, A Manual: Cable-Tension Strength Tests, Chicopee, Mass., Brown-Murphy Co., 1953.

14. Chui, Edward, "The Effect of Systematic Weight Training on Athletic Power", Research Quarterly, vol. 21 (1950), pp. 188 - 194.

15. Masley, John W., Hairabedian, Ara, Donaldson, Donald H., "Weight Training in Relation to Strength, Speed and Coordination", Research Quarterly, vol. 24 (1953), pp. 308 - 315.

16. Pierson, William R., Rasch, Philip J., "Strength and Speed", Perceptual and Motor Skills, vol. 14 (1962), p. 144.

17. Richardson, John, "The Effect of Brief Isometric and Isotonic Exercise Programmes on the Development of Strength and Muscular Endurance", Unpublished Master of Arts thesis, University of Alberta, 1963.

18. Gersten, Jerome W., "Isometric Exercises in the Paraplegic and in the Patient with Weaknesses of Quadriceps and Hamstrings", Archives of Physical Medicine and Rehabilitation, vol. 42 (1961), pp. 498 - 506.

19. Petersen, F. Bonde, "Muscle Training by Static, Concentric and Eccentric Contractions", Acta Physiologica Scandinavia, vol. 48 (1960), pp. 405 - 416.

20. Hettinger, T.L., Müller, E.A., "Muskelleistung and Muskeltraining", Arbeitsphysiologie, vol. 15 (1953), pp. 111 - 126.

21. Smith, Leon E., "Reaction Time and Movement in Four Large Muscle Movements", Research Quarterly, vol. 32 (1961), pp. 88 - 91.

22. Fairclough, Richard H., "Transfer of Motivated Improvement in Speed of Reaction and Movement", Research Quarterly, vol. 23 (1952), pp. 20 - 27.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the relationship between changes in strength of the quadriceps muscle and changes in reaction time and movement time, in a knee extension movement. The relationship between reaction time and speed of movement was also considered. Another sub-problem considered was the relationship between initial strength and initial speed of reaction and between initial strength and initial movement time.

Forty-five male students at the University of Alberta, the majority of whom were enrolled in the required Physical Education program, participated in the study. They were divided into three groups of equal mean RT and MT. One group served as a control group, one as an isometric training group and the other as an isotonic group.

The isometric exercise program consisted of three, six-second maximal contractions, one at each angle of 115 degrees, 135 degrees and 155 degrees. The isotonic group lifted a maximal weight from the 90 degrees flexion position to the 165 degrees extension position over a six-second time period. At the end of the six-second period the weight was removed from the subject's leg. This was repeated twice more after rest periods of 10 and 20 seconds. If the subject could successfully lift this weight, another 1¼ pounds was added to establish a new maximal weight. Both groups exercised four times a week for five weeks.

The subjects were tested twice initially on all three measures of strength, reaction time and speed of movement. Strength was tested by the cable-tension method. Speed of movement was tested by swinging

the lower leg through a 68 degree arc and was measured at four consecutive timing stations spaced at equal intervals of 17 degrees. The subjects were again tested after 2½ weeks of strength training and again after five weeks.

On the basis of the statistical analysis the following conclusions seem justifiable:

1. Both the isometric and isotonic groups gained significantly in strength after five weeks of training four times a week but there was no significant difference between the two exercise groups.
2. Neither speed of movement nor reaction time was increased after five weeks of strength training.
3. There was a significant relationship ($r = 0.538$) between speed of reaction and speed of movement.
4. There was a significant but low relationship ($r = -0.357$) between initial strength and speed of reaction.
5. Initial strength and speed of movement have a significant relationship in the leg movement studied ($r = -0.504$).
6. The individual changes in strength did not correlate significantly with individual changes in movement time or reaction time.

BIBLIOGRAPHY

Barney, Vernon S., "A Comparison of the DeLorme Technique of Progressive Resistance Exercise With a Modified Technique", microcards, Master of Science Thesis, Brigham Young University, 1956.

Barney, Vernon S., Bangerter, Blauer L., "A Comparison of Three Programs of Progressive Resistance Exercise", Research Quarterly, vol. 32 (May 1961), pp. 138 - 146.

Chui, Edward, "The Effect of Systematic Weight Training on Athletic Power", Research Quarterly, vol. 21 (Oct. 1950), pp. 188 - 194.

Clarke, David H., "Correlation Between the Strength/Mass Ratio and the Speed of an Arm Movement", Research Quarterly, vol. 31 (Dec. 1960), pp. 570 - 574.

Clarke, David H., Henry, Franklin M., "Neuromotor Specificity and Increased Speed from Strength Development", Research Quarterly, vol. 32 (Oct. 1961), pp. 315 - 325.

Clarke, David H., Herman, Edward L., "Objective Determination of Resistance Load for Ten Repetitions Maximum for Quadriceps Development", Research Quarterly, vol. 26 (Dec. 1955), pp. 385 - 390.

Clarke, H. Harrison, "Improvement of Objective Strength Tests of Muscle Groups by Cable-Tension Methods", Research Quarterly, vol. 21 (Dec. 1950), pp. 399 - 419.

Clarke, H. Harrison, A Manual: Cable-Tension Strength Tests, Chicopee, Mass., Brown-Murphy Co., 1953.

Clarke, H. Harrison, "Comparison of Instruments for Recording Muscle Strength", Research Quarterly, vol. 25 (Dec. 1954), pp. 398 - 411.

Clarke, H. Harrison, Glines, Don, "Relationships of Reaction, Movement and Completion Times to Motor, Strength, Anthropometric and Maturity Measures of 13-year Old Boys", Research Quarterly, vol. 33 (May 1962), pp. 194 - 201.

Clarke, H. Harrison, Petersen, Kjell J., "Strength Tests of Affected Muscle Groups Involved in Orthopedic Disabilities", Unpublished manuscript, Springfield College, Springfield, Mass., 1945.

Cooper, John H., "An Investigation of the Relationship Between Reaction Time and Speed of Movement", microcards, Doctor of Physical Education dissertation, Indiana University, 1956.

DeLorme, Thomas L., "Restoration of Muscle Power By Heavy-Resistance Exercises", Journal of Bone and Joint Surgery, vol. 27 (Oct. 1945), pp. 145 - 667.

DeLorme, Thomas L., "Heavy Resistance Exercises", Archives of Physical Medicine, vol 28 (Oct. 1946), pp. 607 - 630.

DeLorme, Thomas L., Ferris, Benjamin G., Gallagher, J. Roswell, "Effect of Progressive Resistance Exercise on Muscle Contraction Time", Archives of Physical Medicine, vol. 33, (Feb. 1952), pp. 86 - 92.

DeLorme, Thomas L., Schwab, Robert S., Watkins, Arthur, L., "The Response of the Quadriceps Femoris to Progressive- Resistance Exercises in Poliomyelitis Patients", Journal of Bone and Joint Surgery, vol. 30-A (Oct. 1948), pp. 834 - 847.

DeLorme, Thomas L., Watkins, Arthur, L, "Techniques of Progressive-Resistance Exercise", Archives of Physical Medicine, vol. 29 (May 1948), pp. 263 - 273.

Endres, John Paul, "The Effect of Weight Training Exercise Upon the Speed of Muscular Movement", microcards, Master of Science Thesis, University of Wisconsin, 1953.

Fairclough, Richard H., "Transfer of Motivated Improvement in Speed of Reaction and Movement", Research Quarterly, vol. 23 (March 1952), pp. 20 - 27.

Ferguson, George A., Statistical Analysis in Psychology and Education, McGraw-Hill Book Co., Inc., Toronto, 1959.

Gallagher, J. Roswell, DeLorme, Thomas L., "The Use of the Technique of Progressive-Resistance Exercise in Adolescence", Journal of Bone and Joint Surgery, vol. 31-A (Oct. 1949), pp. 847 - 858.

Garrett, Henry E., Statistics in Psychology and Education, Longmans, Green and Co., New York, 1961.

Gersten, Jerome W., "Isometric Exercises in the Paraplegic and in the Patient With Weakness of Quadriceps and Hamstrings", Archives of Physical Medicine and Rehabilitation, vol. 42 (1961), pp. 498 - 506.

Glines, Don, "Relationship of Reaction, Movement and Completion Times to Certain Motor, Strength, Anthopometric and Maturity Measures, mocrocards, Doctor of Philosophy dissertation, University of Oregon, 1960.

Henry, Franklin M., "Independence of Reaction and Movement Times and Equivalence of Sensory Motivators of Faster Response", Research Quarterly, vol. 23 (Mar. 1952), pp.43 - 53

Henry, Franklin M., "Precision and Operation of the Hundredth - Second Electric Timer", Research Quarterly, vol. 30 (Mar. 1959), pp. 117 - 121.

Henry, Franklin M., "Factorial Structure of Speed and Static Strength in a Lateral Arm Movement", Research Quarterly, vol. 31 (Oct. 1960), pp. 440 - 447.

Henry, Franklin M., "Reaction Time - Movement Time Correlations", Perceptual and Motor Skills, vol. 12 (Feb. 1961), pp. 63 - 66.

Henry, Franklin M., "Stimulus Complexity, Movement Complexity, Age, and Sex in Relation to Reaction Latency and Speed in Limb Movements", Research Quarterly, vol. 32 (Oct. 1961) pp. 353 - 366.

Henry, Franklin M., Lotter, Willard S., Smith, Leon E., "Factorial Structure of Individual Differences in Limb Speed, Reaction and Strength", Research Quarterly, vol. 33 (Mar. 1962), pp 70 - 84.

Henry, Franklin M., Whitley, Jim D., "Relationships Between Individual Differences in Strength, Speed and Mass in an Arm Movement", Research Quarterly, vol. 31 (Mar. 1960), pp. 24 - 33.

Hettinger, Theodor, Physiology of Strength, Charles C. Thomas Publisher, Springfield, Ill., 1961.

Hettinger, T.L., Müller, E. A., "Muskelleistung and Muskeltraining", Arbeitsphysiologie, vol. 15 (1953), pp. 111 - 126

Howell, Maxwell L., "Influence of Emotional Tension on Speed of Reaction and Movement", Research Quarterly, vol. 24 (Mar, 1953), pp. 22 - 32.

Karpovich, Peter V., Murray, Jim, Weight Training in Athletics, Prentice-Hall Inc., Englewood Cliffs, 1957.

Krusen, Edward M., "Functional Improvement Produced by Resistive Exercise of Quadriceps Muscle Affected by Poliomyelitis", Archives of Physical Medicine, vol. 30 (May 1949), pp. 271 - 277.

Kurt, Charles P., "The Effect of Weight Training on Hand-Eye Coordination, Balance and Response time", microcards, Master of Arts Thesis, State University of Iowa, 1953.

Lawrence, Mary S., "Strengthening the Quadriceps: Progressively Prolonged Isometric Tension Method", The Physical Therapy Review, vol. 36 (Oct. 1956), pp. 658 - 661.

Lawrence, Mary S., McGrail, Judith A., "Strengthening the Quadriceps Femoris: Progressive Weighted Isometric Exercise Method", The Physical Therapy Review, vol. 40 (Aug. 1960), pp. 577 - 584.

Lawrence, Mary S., Meyer, Harriet R., Matthews, Nancy C., "Comparative Increase in Muscle Strength in the Quadriceps Femoris by Isometric and Isotonic Exercise and Effects on the Contralateral Muscle", Journal of the American Physical Therapy Association, vol. 42 (Jan. 1962), pp. 15 - 20.

Lotter, Willard S., "Interrelationships Among Reaction Times and Speeds of Movement in Different Limbs", Research Quarterly, vol. 31 (May 1960), pp. 147 - 155.

Masley, John W., Hairabedian, Ara, Donaldson, Donald N., "Weight Training in Relation to Strength, Speed and Coordination", Research Quarterly, vol. 24 (Oct. 1953), pp. 308 - 315.

McGovern, Richard E., Luscombe, Harold B., "Useful Modifications of Progressive Resistive Exercise Technique", Archives of Physical Medicine, vol. 34 (Aug. 1953), pp. 475 - 477.

Meadows, Paul Eugene, "The Effect of Isotonic and Isometric Muscle Contraction Training on Speed, Force, and Strength", microcards, Do ctor of Philosophy dissertation, University of Illinois, 1959.

Meisel, Stephen G., "The Effect of a Weight Training Program on the Speed of Running", microcards, Master of Science Thesis, Pennsylvania State University, 1957.

Mendryk, Stephen, "Reaction Time, Movement Time, and Task Specificity at Ages 12, 22 and 48 Years", Research Quarterly, vol. 31 (May 1960), pp. 156 - 162.

Müller, Erich A., "The Regulation of Muscular Strength", Journal of the Association for Physical and Mental Rehabilitation, vol. 11 (Mar. - Apr. 1957), pp. 41 - 47.

Müller, Erich A., "Training Muscle Strength", Ergonomics, vol. 2 (Feb. 1959), pp. 216 - 222.

Petersen, F. Bonde, "Muscle Training by Static, Concentric and Eccentric Contractions", Acta Physiologica Scandinavia , vol. 48 (1960), pp. 406 - 416.

Pierson, William R., "A Comparison of Fencers and Non-fencers by Psychomotor, Space Perception, and Anthropometric Measures", Research Quarterly, vol. 27 (Mar. 1956), pp. 90 - 96.

Pierson, William R., "The Relationship of Movement Time and Reaction Time from Childhood to Senility", Research Quarterly, vol. 30 (May 1959), pp. 227 - 231.

Pierson, William R., Rasch, Philip J., "Strength and Speed" , Perceptual and Motor Skills, vol. 14 (1962), p. 144.

Rasch, Philip J., "Relationship of Arm Strength, Weight and Length to Speed of Arm Movement", Research Quarterly, vol. 25 (Oct. 1954), pp. 328 - 332.

Richardson, John, "The Effect of Brief Isometric and Isotonic Exercise Programmes on the Development of Strength and Muscular Endurance", Unpublished Master of Science Thesis, University of Alberta, 1963.

Rose, Donald L., "Brief Maximal Isotonic Exercises in the Treatment of Knee Injuries", Journal of American Medical Association, vol. 171 (Nov. 1959), pp. 1673 - 1675.

Rose, Donald L., Radzyminski, Stanley F., Beatty, Ralph R., "Effect of Brief Maximal Exercise on the Strength of the Quadriceps Femoris", Archives of Physical Medicine, vol. 38 (Mar. 1957), pp. 157 - 164.

Schweid, Daniel, Vignos, Paul J., Archibald, Kenneth C., "Effects of Brief Maximal Exercise on Quadriceps Strength in Children", American Journal of Physical Medicine, vol. 41 (Oct. 1962), pp. 189 - 197.

Slater - Hammel, Arthur T., "Reaction Time and Speed of Movement", Perceptual and Motor Skills Research Exchange, vol. 4 (1952), pp. 109 - 113.

Smith, Leon E., "Reaction Time and Movement Time in Four Large Muscle Movements", Research Quarterly, vol. 32 (Mar. 1961), pp. 88 - 92.

Smith, Leon E., "Individual Differences in Strength, Reaction Latency, Mass and Length of Limbs, and their Relation to Maximal Speed of Movement", Research Quarterly, vol. 32 (May 1961), pp. 208 - 220.

Steinhaus, Arthur H., "Strength From Morpurgo to Müller - A Half Century of Research", Journal of the Association for Physical and Mental Rehabilitation, vol. 9 (Sept. - Oct. 1955), pp. 147 - 150.

Wilkin, Bruce M., "The Effect of Weight Training on Speed of Movement", Research Quarterly, vol. 23 (oct. 1952), pp. 361 - 369.

Wilson, Don J., "Quickness of Reaction and Movement Related to Rhythmicity or Nonrhythmicity of Signal Presentation", Research Quarterly, vol. 30 (Mar. 1959), pp. 101 - 109.

Youngen, Lois J., "A Comparison of Reaction Time and Movement Time Measures of Women Athletes and Non-Athletes", Research Quarterly, vol. 30 (Oct. 1959), pp. 349 - 355.

Zorbas, William S., Karpovich, Peter V., "The Effect of Weight Lifting Upon Speed of Muscular Contractions", Research Quarterly, vol. 22 (May 1951), pp. 145 - 148.

APPENDIX

APPENDIX A

STATISTICAL TREATMENT

STATISTICAL TREATMENT

Reliability of the Measurements. Both test-retest and split-half reliability coefficients were computed by use of the Pearson Product-Moment correlation coefficient. The formula used was (1: 92):

$$r = \frac{N\Sigma XY - \Sigma X\Sigma Y}{\sqrt{\left[N\Sigma X^2 - (\Sigma X)^2\right]\left[N\Sigma Y^2 - (\Sigma Y)^2\right]}}$$

where X = test score or odd half score

Y = retest score or even half score.

Tests of Significance. The t-ratio was obtained by the use of tests for significant differences between means for correlated samples. The formula used was (1:138):

$$S_D^2 = \frac{\Sigma D^2 - \frac{\Sigma D^2}{n}}{n - 1}$$

$$S_{\bar{D}}^2 = \frac{S_D^2}{n}$$

$$t = \frac{\bar{D}}{\sqrt{S_D^2/N}}$$

The t-ratio from the tests of significance for independent samples was derived from the formula (1:137):

$$s^2 = \frac{\Sigma(X-\bar{X}_1)^2 + \Sigma(X-\bar{X}_2)^2}{N_1 + N_2 - 2}$$

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(s^2/N_1) + (s^2/N_2)}}$$

Homogeneity of variance was derived from the formula (1:143):

$$t = \frac{(S_1^2 - S_2^2)\sqrt{N - 2}}{\sqrt{4S_1^2\ S_2^2\ (1 - r_{12}^2)}}$$

Analysis of Variance. The F - ratio was obtained from analysis of variance: one-way classification (1:237):

Subjects	Group I	Group II	Group III	
1	___	___	___	
2	___	___	___	
3	___	___	___	
.	.	.	.	
.	.	.	.	
.	.	.	.	
15	___	___	___	
n_j	___	___	___	N
T_j	___	___	___	T
$\bar{X}_j$	___	___	___	T^2/N
$\sum_{i=1}^{n_j} X_{ij}^2$	___	___	___	$\sum_{j=1}^{K}\sum_{i=1}^{n_j} X_{ij}^2$
$\frac{T_j^2}{n_j}$	___	___	___	$\sum_{j=1}^{K}\frac{T_j^2}{n_j}$

	Sum of Squares
Between	$\sum_{j=1}^{K}\frac{T_j^2}{n_j} - \frac{T^2}{N}$
Within	$\sum_{j=1}^{K}\sum_{i=1}^{n_j} X_{ij}^2 - \sum_{j=1}^{K}\frac{T_j^2}{n_j}$
Total	$\sum_{j=1}^{K}\sum_{i=1}^{n_j} X_{ij}^2 - \frac{T^2}{N}$

ANALYSIS OF VARIANCE

Between $\div$ $k - 1 = S_b^2$

Within $\div$ $N - k = S_w^2$

Total $N - 1$ $F = \frac{S_b^2}{S_w^2}$

REFERENCES

1. Ferguson, George A., Statistical Analysis in Psychology and Education, McGraw - Hill Book Company, Inc., Toronto, 1959.

APPENDIX B

INDIVIDUAL SCORE SHEET

RT - MT TEST SHEET

TEST NO. ________

NAME ________________________________ AGE ________

ADDRESS ________________________________ PHONE ________

GROUP 1 2 3 TIME ________

Trial No.	RT	1	2	3	4
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Total					
Mean					

Trial No	Score	Strength
1		
2		
3		

FINAL STRENGTH ________

APPENDIX C

RAW SCORES

STRENGTH

Pounds

	Isometric			Isotonic			Control		
No.	1	2	3	1	2	3	1	2	3
1.	336	350	360	240	290	290	355	355	380
2.	260	320	360	400	410	440	224	232	236
3.	177	216	264	248	268	315	260	305	320
4.	280	264	272	128	177	183	272	220	285
5.	296	334	350	248	252	310	236	248	256
6.	310	367	393	173	194	204	236	290	272
7.	380	393	400	285	315	305	285	280	280
8.	208	248	280	272	280	310	340	355	340
9.	240	268	248	248	300	280	240	285	305
10.	290	333	380	260	248	272	228	264	248
11.	204	272	260	200	224	248	336	326	340
12.	186	208	256	290	315	327	280	272	268
13.	190	183	232	237	240	300	180	153	167
14.	280	256	295	320	355	393	320	320	295
15.	224	224	240	208	290	355	300	320	333

1 - Initial Test
2 - Half-way Test
3 - Final Test

REACTION TIME

Seconds

	Isometric			Isotonic			Control		
No.	1	2	3	1	2	3	1	2	3
1.	.223	.208	.195	.284	.243	.266	.250	.235	.234
2.	.196	.202	.214	.225	.228	.195	.238	.220	.225
3.	.232	.210	.226	.215	.192	.210	.238	.271	.286
4.	.215	.222	.212	.352	.301	.298	.296	.235	.243
5.	.236	.236	.241	.250	.228	.215	.262	.245	.228
6.	.198	.205	.199	.214	.201	.200	.200	.191	.207
7.	.238	.227	.226	.190	.182	.198	.274	.260	.216
8.	.203	.221	.191	.221	.198	.201	.220	.222	.227
9.	.232	.227	.225	.215	.208	.194	.262	.254	.258
10.	.240	.208	.229	.262	.246	.244	.259	.228	.241
11.	.347	.325	.305	.228	.215	.184	.228	.212	.214
12.	.253	.219	.217	.228	.230	.213	.234	.231	.240
13.	.299	.264	.280	.230	.253	.225	.248	.247	.227
14.	.206	.212	.190	.187	.188	.180	.206	.214	.188
15.	.215	.211	.220	.207	.203	.202	.249	.243	.233

1 - Initial Test
2 - Half - way Test
3 - Final Test

MOVEMENT TIME

Seconds

	Isometric			Isotonic			Control		
No.	1	2	3	1	2	3	1	2	3
1.	.127	.125	.119	.132	.127	.132	.102	.102	.095
2.	.132	.124	.118	.129	.128	.124	.130	.141	.144
3.	.151	.152	.139	.154	.140	.135	.129	.135	.121
4.	.103	.123	.121	.217	.184	.161	.170	.170	.174
5.	.122	.127	.112	.142	.141	.124	.107	.117	.111
6.	.133	.140	.120	.116	.144	.119	.142	.142	.132
7.	.129	.141	.130	.095	.104	.099	.132	.131	.120
8.	.118	.121	.108	.117	.114	.112	.104	.112	.118
9.	.141	.131	.135	.123	.124	.116	.128	.147	.128
10.	.114	.113	.117	.110	.114	.124	.151	.144	.136
11.	.165	.149	.164	.128	.140	.122	.120	.116	.126
12.	.130	.134	.122	.133	.123	.125	.141	.145	.141
13.	.158	.168	.176	.142	.141	.161	.153	.148	.140
14.	.096	.108	.105	.103	.102	.105	.120	.127	.115
15.	.136	.127	.118	.114	.122	.104	.117	.119	.113

1 - Initial Test
2 - Half-way Test
3 - Final Test